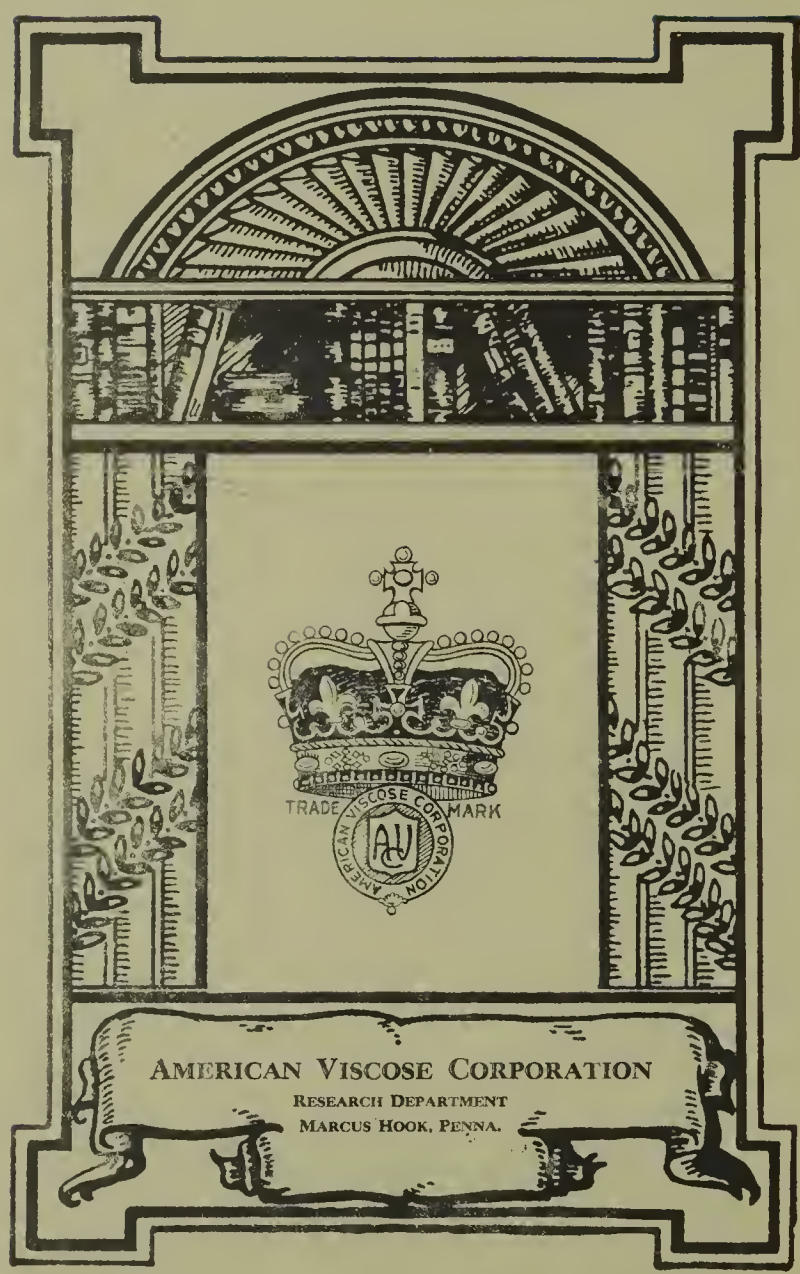
Edward Barton



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Volume XI.—Page 73.

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TRANSACTIONS

OF THE

AMERICAN INSTITUTE

OF

CHEMICAL ENGINEERS

VOLUME XII—PART II

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TRANSACTIONS OF THE AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

CHEMISTRY AND THE SOUTH

By President ARTHUR D. LITTLE

Read at the Savannah Meeting, Dec. 3, 1919

The American Institute of Chemical Engineers is composed of men who are, above all, intensely practical: men who make it their like work to apply chemistry to useful ends. We have come to Savannah not merely to enjoy a proverbial and graciously extended hospitality, but chiefly because we recognize that here there is much for us to learn. Your cotton oil mills, your great fertilizer factories, the secrets of your naval stores industry, the doors of many plants distinctively Southern in their type have been generously opened to us. We shall take with us on our return new and enduring impressions of Southern courtesy and kindliness, convincing evidence of the magnitude of industrial achievement in the South, and a new appreciation of the wealth of resource and of opportunity in this supremely favored section of our country, but our mission will have failed unless we leave behind us a message so vital and direct in its importance that it secures and holds your attention and thereafter influences your action.

It is no new message: it is the same in import as that carried by the American Electrochemical Society on its Southern tour in 1918; it was voiced and developed by many authorities of national reputation in the remarkable issue of September 14, 1916, of the Manufacturers Record; it has appeared on many editorial pages and in many government publications, and I myself have had the privilege of bringing it to representative bodies of Southern scientists and business men. And that message in a word is this: *The Future of the South is in Chemistry.*

To ensure acceptance any such general thesis properly requires demonstration. Suppose we begin by considering for a moment what the South already owes to chemistry.

The manufacture of fertilizers and the effective use of these artificial manures in the growing of crops are obviously based on chemistry and controlled by the laboratory findings of works chemists, the experiment stations, and the Bureau of Chemistry. The farmer, wiser than most purchasing agents, buys on analysis. Agricultural chemistry, with all that it means to the South, began in the laboratory of Liebig and gained recognition in this country chiefly through the writings and work of Johnson. The essential elements with which growing crops must be supplied are potash, ammonia, and phosphoric acid. It was the refined and classic work of the Dutch chemist, Van't Hoff, in physical chemistry which rendered possible the separation of the potash from the salts of the Stassfurt mines; the world has long derived its ammonia from the chemical processes of the gas works and by-product coke ovens; to-day it turns to the atmosphere for the larger supplies of ammonia and nitric acid which its growing needs demand and secures them by the chemical and electrochemical methods of nitrogen fixation, which, incidentally, have placed new values on Southern water powers. The nitrogenous fertilizer, cyanamid, is a direct descendant of calcium carbide, first produced commercially by Willson at Spray, North Carolina. The essential constituent of phosphate rock is rendered available by treatment of the rock with that basic chemical product, sulphuric acid, while chemical processes have brought into use and service the low grade ores contaminated with fluorine and alumina.

At the recent World's Cotton Conference in New Orleans it was stated that in growing cotton there was used on a one-horse twenty-seven-acre farm selected as a type six and three-fourth tons of fertilizer worth $391.50 and one ton of nitrate of soda worth $90.00. The figures gain significance when we consider that the pre-war acreage, now somewhat reduced, was 37,000,000 acres.

Upon this vast expanse the South has annually raised for years an average of about 13,000,000 bales of cotton. The 1919 crop is estimated at 11,000,000 bales of staple worth about $150 a bale with 5,000,000 tons of seed valued at $70 a ton—a total increment to Southern wealth of at least $2,000,000,000.

In no small proportion these values are due to chemistry. If

they are attributed to the war we have only to reply that without chemistry the war could not have been fought at all, while in the absence of gun-cotton, which is merely cotton plus chemistry, it could only have been fought at great disadvantage to our allies and ourselves.

But we are happily now concerned with the peace time uses of cotton. How far has chemistry extended them and put new values on the cotton crop? Cotton bleaching, which permits its use in fabrics of the finer sorts, is based primarily upon the discoveries of Scheele, Weldon, LeBlanc, and Solvay, chemists all of them, and with the exception of the discoverer of chlorine, chemical engineers. Dyeing and printing, which so greatly promote the sale of cotton fabrics, involve pretty much the whole range of chemistry and are tied into its most modern developments, physical and colloid chemistry. The mercerizing process as ultimately developed by Thomas and Prevost imparts to cotton a wonderful silky luster and resulted in an enormous extension of its use in fabrics of the higher grades.

The automobile, you may be surprised to learn, is a chemical product. It could not exist without the high speed tool steels which fabricate its parts and which had their origin in the laboratory, the aluminum which forms its bodies, the artificial leather which provides covering and permits style with cheapness, the special alloys which combine strength with lightness, the methods which produce gasoline at the casing head in gas fields, the research behind the rubber tire.

You will again be surprised to know that at least 2,000,000 spindles are to-day engaged in the business of converting cotton into automobile fabrics. 150,000 tires are consumed daily. Within one or two years the tire production will have increased by 50%, and spindles to the number of 1,000,000 more in this one industry will call to the South for new supplies of cotton.

Cotton in its purified forms is the type of that wonderful substance, cellulose, the structural basis of all plants and, thereby, the greatest structural material in all the world. The South has an interest in the chemistry of cellulose for of it her forests are builded and on it her entire agriculture depends. The discovery of nitrocellulose by Schönbein, in 1845, has resulted in an extraordinary concatenation of industrial, economic, and political consequences. From it came smokeless powder, the guncotton in the war heads of

German torpedoes, the collodion of the surgeon, artificial silk, celluloid in countless shapes, substitutes for leather, the moving picture films, the finish on brass beds, and the eyelets on our shoes. The South must credit Schönbein with the values placed on cotton linters and the shorter fibers adhering to the hull.

A more recent but analogous compound, cellulose acetate, made by treating cotton with acetic anhydride and sulphuric acid, has already attained an importance only secondary to the nitrate in the arts of peace and war. In the form of cellulose acetate Southern cotton functioned high above the battlefields of Europe as the protective covering of airplane wings. To the same compound we are indebted for non-inflammable moving picture films, for artificial silk of an altogether new order of merit, artificial bristles and horsehair, and for a substitute for celluloid wholly free from the dangers which always attend the manufacture and which sometimes accompany the use of this ubiquitous material.

But chemistry does not stop with the cotton fiber; it has enriched the South still further in the values it has put upon the cottonseed which once clogged Southern streams. Cottonseed to-day is worth $70 a ton because chemists have derived from this nuisance of pre-bellum days—it is hard to recall the Civil War, to which I now refer—edible oil, a solid substitute for lard, soap stock, a concentrated cattle feed, and residues of high fertilizing value. On these I need not dwell since you are soon to have the privilege of listening to David Wesson, who is 99-44/100 per cent pure cotton oil and who will speak of these developments with the authority of one who has achieved them.

Southern bauxite, without chemistry, is merely a stone to throw at a dog. With chemistry, it controls the aluminum industry of the world. Louisiana sulphur lay secure beneath 500 feet of quicksand until the chemical engineer, Frasch, brought it to the surface by methods so simple and so cheap that the groaning *Carusi* of Sicily were released from their intolerable burdens and set to work in sunshine on the soil whereunder they had toiled.

But why has sulphur any value in Sicily or Texas or Louisiana? Solely because the coördinated studies of generations of chemists have made it the foundation stone of modern chemical industry. As such it functions in sulphuric acid in countless reactions through the whole range of manufacture.

The largest sulphuric acid plant in the world is at Ducktown,

Tennessee, but here the acid is made from smelter fume and constitutes a striking example of a nuisance transformed by chemistry into a profit.

Eight hundred tons of Southern sulphur are used each day in America alone, to an annual value of $7,000,000, because fifty years ago Tilghman, in Philadelphia, applied chemistry to the production of wood fiber for use in paper making.

Because Braconnot, in 1819, converted cellulose to fermentable sugars, great plants are now operating in Louisiana and South Carolina converting the wood wastes from yellow pine lumber mills into ethyl alcohol. A Southern chemist, Charles H. Herty, held in honor and affection by chemists everywhere, has revolutionized your naval stores industry. Moreover, an actual $500,000 and a potential $1,000,000 at least has been added to the annual value of the turpentine crops by a simple change in chipping method based on studies made in France on the pathology of the wounded tree.

I have tried to indicate by a few examples what chemistry has already accomplished for the South, but these meager references will have failed altogether of their purpose unless they have developed in your mind the incomparably larger and panoramic picture of the expanding chemical industries of the South.

Statistics often prove without convincing. They may compel the reason to assent without firing the imagination or arousing the will to action. I believe, however, that no one with the capacity to understand their true significance can review the colossal figures which set forth the natural resources of the South without first being stunned and overwhelmed and soon thereafter filled with the vision of their stupendous possibilities. These figures are readily available in government and State reports and the papers of many experts, and I have at other times brought many of them together. I do not propose to marshal them before you this evening. They are doubtless already familiar to many of you. For our present purpose they may be summarized in the statement that the South contains in superabundant measure the basic raw materials required for the development of great groups of coördinated industries founded upon chemistry and on a scale incomparably more vast than anything yet known. She has more than half the iron ore in the United States and 75% of all the coking coal; great stores of lignite, natural gas, and oil. Here is the purest salt which occurs

in nature, the cheapest and purest sulphur, clays endless in variety and extent, bauxite for aluminum and for abrasives, limestone adjacent to coal and iron, phosphate rock, gypsum, barytes, shale and quartz, ores of zinc and manganese, lead and nickel, titanium and tin. There is enough wood waste to supply the country's need for paper, and the world must soon look to the stumps on millions of acres of cut-over lands for its rosin and its turpentine. The cotton fiber is itself the raw material for many chemical industries of magnitude, and the short hull fiber, to utilize which in smokeless powder huge Southern plants were built, is now available for paper making and other arts of peace. The products and the potentialities of the cotton seed now have a rival in the humble peanut and in at least one Southern locality the peanut crop exceeds the cotton crop in value. In the South as a whole the value of the corn crop already approximately equals that of cotton and affords a basis for great corn product industries. To such material resources with many others, to which no reference can here be made, the South adds the potentialities of 5,000,000 horse power in the available energy of her streams.

The South is no stranger to chemical developments on the great scale. The largest electrolytic copper plant in the world refines 720,000,000 pounds a year at Canton, Maryland; Ducktown, Tennessee, produces 1000 tons of sulphuric acid a day. The war called forth in Sheffield, Alabama, nitrate plants designed for a carbide production equal to that of the entire continent and for 100,000 tons of ammonium nitrate yearly. The Old Hickory Plant at Nashville had an estimated cost of $90,000,000 and in nine powder lines, each of a capacity of 100,000 pounds a day, took the raw crude cotton and, producing both the acids and the solvents used, turned out the finished powder. The plant at Nitro, West Virginia, was designed for 625,000 pounds a day of powder. To the South must also be credited the great plant of the du Ponts at Hopewell.

These industrial achievements, stupendous though they are, derive their chief significance as evidence and measures of what will be accomplished in the South when capital joins hands with chemistry in the coördinated development of Southern resources.

J. W. Richards wisely and truly says, "The industries are fundamentally based on the imagination." Those who would share in this great development must mix imagination with statistics and have the courage to accept their findings and the initiative to act on them.

What then may Chemistry be reasonably expected to accomplish in the South? And how?

With increasing density of population in the South and throughout the country a more intensive agriculture must everywhere be practiced. A great expansion of the Southern fertilizer industry, already so important, would seem to be assured. Improved methods of production will check the abnormal wastes which now accompany the mining of phosphate rock, raise the intrinsic value of the product, and permit of larger profits. The potash content of the gray iron ores of Alabama will be rendered available, presumably by the Cottrell process, and supplied to agriculture as a by-product of the blast furnace. From the expanding Portland cement industry more by-product potash will be similarly derived. Ammonia from by-product coke ovens will be recovered in vastly greater quantities. Some extension of cyanamid production may be expected, but the vast stores of cheap nitrates and ammonia which the new agriculture will demand will come from the atmosphere by direct nitrogen fixation methods. Southern water powers will play an important, although not necessarily a controlling part in their development. In the best interests of the South, it is in any case desirable that they be not linked up too exclusively to electrochemical processes since these create relatively little opportunity for labor. It is incomparably more advantageous to constitute the water powers the centers of diversified and highly developed manufactures, the economic value of which may be a hundred times that of the water powers themselves.

It is probable, nevertheless, that for a generation or two at least Southern water powers are to find their chief applications in the field of electrochemistry, which is already extensive enough to ensure a considerable diversity of industry. More and more will the electric furnace become a factor in the steel industry in the smelting of steel itself and in the production of ferro-alloys of silicon, titanium, manganese, and vanadium with others yet to come. It will doubtless be applied to the product of the cranberry iron ore of Kingsport, Tennessee, the purest ore in the United States. Such furnaces also will function far more generally in the production of non-ferrous alloys, abrasives, carbide, and other products now unknown. Methods of electrolysis will utilize much hydroelectric energy in making chlorine and alkali, chlorates, peroxides, perborates, and persulphates.

The extraction of aluminum from bauxite is at last well established as a Southern industry at Maryville, Tennessee. In Alabama are great beds of bauxite only seventy miles from water power and with rich seams of coal between. But the production of aluminum is destined to be far more closely identified with the South. Ultimately will come effective and economical methods for the direct extraction of the metal from clay. Then each of the immense deposits of kaolin in the mountains of Virginia, the Carolinas, Georgia, Florida, and Alabama will be reconstituted as mines of aluminum ore.

The variety and range of character exhibited by Southern clays is amply sufficient to meet every requirement of the ceramic industries from bricks, tiles, and terra cotta through pottery to porcelain. In many instances, the finer sorts have had their usefulness restricted by the presence of titanium minerals in small proportions. Here again chemistry has played its part by demonstrating a simple and inexpensive method for the removal of these impurities, with the result that the purified clays are suitable for the finest china wares and porcelain. In the pegmatic dykes of the Appalachian region are great deposits of very pure quartz awaiting the enterprise of the glass maker.

Our present methods of utilizing coal are wasteful in the extreme. To set free its energy values we commonly employ means which wholly ignore its far greater chemical values. Moreover, bituminous coal, which constitutes the bulk of our supply, is not a desirable fuel for use in cities, and our supply of anthracite is down to 190 tons per capita. Our railroads are breaking down under the strain already put upon them as transportation agencies, and about one-third of their tonnage is coal. All this points to a radical readjustment of our use of coal and to a readjustment which should enormously benefit the South. It means that coal must be burned much nearer to the mine in super-power plants and its energy delivered to great common carrier transmission lines for power linked to hydroelectric developments and operated in coördination with them. It also means huge gas works in which the chemical values of the coal are saved as ammonia and tar, the coke converted into artificial anthracite, and the gas made available for distribution for light and heat and power over wide areas. There will follow as a consequence, a corresponding development of the higher industries based upon the chemical values thus conserved,

and producing dyes, intermediates, synthetic drugs, and new types of coal-tar products. Lignite and peat will ultimately be involved in these comprehensive plans and yield their enormous quota of gas, ammonia, and briquettes.

Natural gas, of which the South now yields 80 per cent of the country's whole supply, has not only been wasted shamelessly, but was long regarded merely as a cheap and convenient fuel. We are now coming to realize that it has values and potentialities far beyond those of the thermal units it contains. Hundreds of plants now extract gasoline at the casing head, and the gas itself is recognized as a raw material available for many organic syntheses, as, for example, chloroform. Certain wells, notably those of Petrolia, Texas, have assumed an altogether new importance as sources of helium, urgently required for airships because of its high lifting power, non-inflammability, and low rate of dispersion through balloon fabrics.

Friction will bring the industries of the world to a standstill unless they are provided with a continuous and assured supply of lubricants, and these are practically all derived from petroleum. The impending exhaustion of the petroleum fields of the South is thus a matter of deep concern wherever wheels turn or machinery functions. The rapidly increasing and already extensive use of fuel oil is therefore an economic blunder which one day may be characterized as worse than a crime. Such oil as remains should be conserved until with incomparably greater benefit to the South due provision is made for utilizing its higher values in the production of lubricants, dyes, and intermediates and the synthesis of gasoline by methods which Rittman, Cherry, and other chemists have already indicated. It is important to remember that the asphaltic oils of the South are more reactive and therefore much more generally available for the higher syntheses than the oils of Pennsylvania, which have a paraffin base.

The wet methods of metallurgy as exemplified in the cyanide and chlorination processes have upset the economic balance of the world through the inordinate increase in gold production due to them. It may be regarded as certain that other wet methods will be developed, and it may easily be soon, which will render possible the profitable working of the great beds of low-grade ores of various metals existing in the South, as, for instance, the nickel ores of Georgia or the low-grade zinc ores of Missouri.

It needs no prophet to point out the inevitable vast extension in the South of the iron and steel industry, already firmly established on the great scale. Around it will naturally evolve groups of associated and dependent manufactures, potash and slag cement, chemically pure iron and special alloys, plants for working up the by-products of the coke oven, new foundries and plate and wire mills and all the multitudinous activities based on steel and controlled by chemistry.

The basic chemical products, sulphuric acid, soda, bleaching powder and others known collectively as heavy chemicals, require for their manufacture sulphur, salt and limestone. Nowhere are these essentials available more profusely than in Louisiana, and the potentialities of their concurrence magnified by their proximity to the great Caddo gas field, the oil of Texas and Louisiana, and the cheap coal of Alabama.

The world now depends chiefly upon the South for its supply of rosin and of turpentine. Both are relatively crude products, and for the most part crudely used. Yet rosin is the cheapest organic acid available to chemistry, and should be made to yield, by well-directed research, products of higher value and wider range of use. Turpentine is also the cheapest volatile oil, and clearly indicated as the logical starting-point for many syntheses. It is already the raw material for synthetic camphor, and camphor is worth $3 a pound.

The end of the virgin supply of crude turpentine is already in sight, and much nearer than is generally realized. Fortunately for the South and for the world, chemistry has performed the double service of demonstrating that cut-over lands may profitably be cleared and new supplies of rosin, turpentine and pine oil extracted from the encumbering stumps of long-past lumbering. Even from the spent chips of the extraction plant excellent Kraft paper has been made.

In the future the South must look for much of its prosperity to the utilization of present wastes. They are colossal in its lumber industry, in gas and oil and agriculture. A ton of straw, for example, will yield 11,000 feet of gas or 800 pounds of high-grade paper. Great stores of ethyl alcohol, rosin, turpentine, gas and tar and many thousand tons of paper container and building boards, fruit wrappers, bags and twine are potentially present in the wood waste burned in the South each day.

The high price of pulp wood has arrested the development of paper-making in the North, and for the next decade at least the expansion of the industry will be in the South, which offers the cheapest pulpwood on the continent outside of Alaska, and in close association thereto, the raw materials required for its production.

To ensure these benefits the South needs, as recently pointed out by Coates, the creation of an atmosphere in which the spirit of manufacturing enterprise may develop freely. It still lacks an adequate number of industrial leaders. It needs far more chemists, and should place far more trust in those it has. It needs recearch, and more research.

Transportation, always a basic factor in the development of industry, is destined in a future nearer than many of us realize, to become a controlling economic influence, not only in the South, but throughout the country as a whole. The annual tonnage consumption of Americans as individuals is rising by leaps and bounds. It already strains our railroads to the breaking point, and will soon attain a volume far beyond any conceivable increase in their carrying capacity. The approach of this situation, inevitable even under the action of normal agencies, has been immensely accelerated by the high wages now prevailing and likely to continue in force for an indefinite period. This means that the day of the long haul for raw materials and the cruder commodities is rapidly coming to a close. It means that communities, and notably the South, must become more nearly self-sustaining, and that the things which they ship out must represent brain values and labor values to an extent unapproached before. It is well in this connection to remember that to move the cotton crop alone requires 1,000,000 carload units.

Fortunately for the South, since it prolongs the period of adjustment, it is not wholly dependent upon the railroads. It has in the Mississippi a great arterial water system, though a sadly neglected one, and its Gulf and Atlantic Coast line stretches along three-fifths of the entire salt-water coast of the United States.

Obviously, nevertheless, and in constantly increasing measure the South must base its prosperity on a diversified agriculture, which shall supply more and more of its own needs, and on such concurrent development and extension of its industries as shall insure the working up at home into products of much higher value the raw materials which it now ships out to have their value en-

hanced elsewhere. The South cannot afford indefinitely to repurchase its own cotton as dress goods, its cotton oil as a lard substitute, its bauxite as aluminum kitchen ware, its pig-iron as stoves, its clays in paper or French china. This means that the time has arrived when the South chemistry begins at home, for, as put by Dr. Charles H. Herty, who knows the South and its requirements as few chemists do, "True progress in any industry must be based, not on individual opinion, or hereditary teachings, but upon scientific research and constant striving for greater efficiency."

The ancient Phœnicians were bold navigators while the stars shone. They were at the mercy of chance under a clouded sky or in a fog. To-day no captain in his senses thinks of taking a ship to sea without compass, charts, tide tables, chronometers, sextants, and a log. He allows for ocean currents and the fact that the earth is round. In a word, he utilizes the facts and instruments of science to steer his course and bring his ship to port. Yet many a modern business is guided by those whom I was about to call Phœnician captains, but that would be unjust to the Phœnicians. They made the most of what little knowledge their world contained. The archaic industrial captains to whom I refer turn their backs on the compass, sextants and chronometers which science has placed ready to their hand, and put to sea, trusting the stars will always shine by night and the sun by day. It is not surprising that they lose their course in cloudy weather or go on the rocks in the first fog. Disdain of science and a contented ignorance of chemistry, which is the most inclusive science of them all, constitute one of the chief reasons why 220,000 American corporations earn less than $5000 a year. Chemistry differs from Fortune in that she is not blind. She bestows her benefits with open eyes, and they go to those who are ready to receive them. The South is not yet quite ready; it should get ready!

THE HISTORY AND DEVELOPMENT OF THE COTTON SEED OIL INDUSTRY IN AMERICA

By DAVID WESSON

Read at the Savannah meeting, Dec. 4, 1919

It seems particularly appropriate at this first meeting of the Institute of Chemical Engineers in a Southern city that an effort should be made to tell the story of how a great industry has been founded and built up on what was once a by-product and a nuisance.

The early records do not tell us much. We find in the statistics of South Carolina, published 1826, that Dr. Benjamin Waring established the first paper, oil, and grist mill at Columbia, S. C., and expressed from the cotton seed a very good oil.

Georgia had an oil mill in 1832 but little is known about it. C. D. Arfwedson, Esq., an English traveler, in his book entitled "The United States and Canada, 1832, 1833 and 1834," states: "In many places it is usual to manure the fields with the seed not used for planting, but of late years experience has taught the planters to set a higher price on it as it contains a considerable quantity of oil which is extracted by pressure and is suitable both for burning and painting. The oil may in the course of years become an additional source of wealth to the planters."

Up to the time of the Civil War and in fact for sometime after, the disposal of the seed was always more or less of a problem. Much of it was used for fertilizer, and a great deal of it was thrown into the water courses.

In 1857, the state of Mississippi passed laws fining gin owners who allowed seed to accumulate at gins located near towns and villages, where it was apt to become a nuisance. The fine was $20 per day after the 5th day.

Another law imposed a fine of $200 for throwing the seed into water courses, the waters of which were used for drinking and fishing.

The industry began to assume some importance just prior to the Civil War, after which it commenced to grow.

In 1860 there were 7 factories employing 183 workers. In 1870, 26 factories employed 644 workers, while to-day about 900 factories give employment to about 20,000 workers and 5000 officers and other salaried men.

The causes for the rapid growth of the industry are various.

First, the rapid increase of population all over the civilized world made increased demands for food. The doing away with the large cattle ranches of the West reduced the meat supply so that the hogs which formerly furnished an adequate supply of lard were more and more eaten as pork and a demand was made for an edible fat to replace the lard. This demand is largely met at this time by cotton seed oil and the growth of the cotton seed oil industry is largely coincident with the decrease per capita of the hog lard supply.

Second. The cotton seed oil produced in the early days of the industry was very irregular in quality. In 1879 it was used in small quantities to adulterate lard, but the quality was such that it did not improve the mixture. The application of chemistry to the industry at this time started it upon a rational basis and gave such a stimulus that it has grown by leaps and bounds ever since. The advent of the chemist started improvements in the quality of the oil and at the same time pointed the way to economies in production.

The most important work of the chemist has been in refining the oil and improving the products made therefrom. To do this principles had to be established in the laboratory and applied in the factory. In 1885 all the chemists in the industry could have been counted on the fingers of one hand. This included near chemists.

At that time the duties of a refinery chemist included testing the oils, refining them, and finally shipping them in suitable cooperage. To do this he had to run pumps and engines, boss the coopers and steam fitters and be a steam fitter himself in an emergency. There were no eight-hour-day with Saturday afternoons off and needless to say the early chemists earned their pay and incidentally the refinery force did likewise.

The young man fresh from school and thrown on his own resources in a refinery soon became a chemical engineer without knowing it. In some ways the chemists of those days had an

advantage over those of to-day. They were blazing their way through an untrodden field little hampered with enlightening literature. They were guided largely by their ingenuity and experience, which later gave them a great advantage. In those early days any one who could refine crude cotton seed oil was regarded almost as a demigod. Very few of the early refiners employed chemists and depended entirely on trained workmen. Many of them were negroes. Little attention was paid to loss. Caustic soda was added by rule of thumb and the losses were enormous. Where losses were estimated, the measurements were crude. I have in mind one manufacturer who pumped all the oil from the crude mill to his refinery where it was refined by a $2 a day negro with marvelously small losses. The owner was always bragging how much better Sam could do than any high priced chemist. The time came when this outfit was put under my jurisdiction and on investigation it was found that Sam was always charged with much less crude oil by the mill than he actually received, which was of course a great help in cutting down the apparent refining losses. As a matter of fact, Sam was actually running about 2 per cent behind plants operated under chemical control.

The early conditions have been presented at considerable length, so as to obtain a good starting point from which to sketch the effects of applied chemistry on the industry.

As the oil and its products constitute the important end of the industry it seems logical to talk about them first:

The first crude oil was used for paint and burning in lamps. The early refineries kept their methods so secret that it has been difficult to discover when oil was first refined in this country. The writer remembers being told in 1870 that peanuts were pressed to obtain oil which was mixed with that of the cotton seed and sold for olive oil.

The early refineries were connected with the oil mills, but there soon arose people who recognized that refining the crude oil as furnished by the mills was an industry by itself and refineries started in several places.

The crude oil in the early eighties was sold on color and flavor and in case of disputes referred to committees. About this time the chemists discovered that free fatty acid in the crude oil was an index of quality and refining loss and applied the test in judging value of samples. A small refining was made to see if the sam-

ples of crude would refine to a good color. The writer used this method in Chicago in 1887 and when in 1890 commenced to reject oil in New York on account of high acidity encountered much opposition, some mill owners protesting that they had never had any fatty acids on their premises.

Shortly after 1880, cotton seed oil began coming to Chicago in considerable quantities. Here it was refined with caustic soda, bleached with fuller's earth, mixed with prime steam lard and oleo stearine and went into commerce as refined lard.

In 1887, it was discovered that more lard was shipped from Chicago than came there either on the hogs killed there or as lard itself. Congress started an investigation and discovered that cotton seed oil was the cause of this great increase. They also discovered that the 30 to 40 per cent of oil in the compounds did not injure them from a health standpoint, though the oil used at that time did not improve the flavor.

About 1892 or 1893, the practice of deodorizing was started in Chicago. This consisted in heating the oil in a tank provided with a large steam coil and then blowing live steam through the oil to remove flavor and odor; the oil was afterward cooled to normal temperature. This process while producing a greatly improved oil did not turn out a perfect one by any means. It allowed the lard substitute maker, however, to use a mixture of about 82 per cent of oil and 18 per cent of oleo stearine, which proved quite satisfactory to the trade.

In 1899, the "Wesson Process," so called, was discovered and the first plant was put in operation in Savannah the following year. The product of this plant set a new standard for cotton seed oil which has now become the chief source of edible fat next to butter in this country. From the discovery of the Wesson Process to about 1910, lard substitutes were made almost entirely of mixtures of oleo stearine and deodorized cotton seed oil. The packer controlling the former put its price very high and the demand for a cheaper material was supplied by the discovery of the hydrogenation process which fulfilled the dream of the fat chemist by furnishing a ready means of saturating the double bonds of the fluid oils with hydrogen and converting olein and linolein to stearine. By passing hydrogen gas through oil at a temperature of 180 to 200° C. in the presence of finely divided nickel cotton seed oil can be hardened to any extent up to a melting point of about 60° C.

The lard substitutes of the present day are almost entirely produced either by partially hardening the whole oil or by adding about 15 per cent of the completely hardened oil to that which has not been so treated.

Besides the use of the oil in lard substitutes which utilizes at present about 75 per cent of the total production, large quantities are used for table oils, oleo margarine or margarine as it is called in Europe. Considerable oil is also used in medicine.

In refining the oil an average of 9 per cent is taken out by the alkali in the form of soapstock. In the early days this was made into cheap laundry and mill soaps. Later it was made into washing powder by first saponifying and washing, then mixing with soda ash or sal soda.

At best the soaps made directly from the soap stock were poor in color and possessed an unpleasant odor.

It is the practice in several large plants to decompose the soap stock with acid, then saponify by the Twitchell process or otherwise and distill the fatty acids from the black elastic pitch which remains. This pitch is used in making paints used for roofing. During the war considerable quantities of glycerine were recovered from the soap stock, but on account of changed conditions it has been found better to treat the soap stock with centrifugal machines of the cream separator type and recover a considerable quantity of the entrained neutral oil.

The first crude oil mills were somewhat primitive compared with those of the present day.

No attempt was made to separate the lint from the seed before passing through the hullers. In those days the seed carried so much lint it was customary to figure meats and hulls as equal in quantity. The early mills burned the hulls under the boilers together with the trash in the seed. The separation was very poor and the hulls frequently carried large quantities of uncut seed and meats which helped account for the high hull percentage.

The separated meats were crushed between rolls, cooked in jacketed heaters and pressed in box presses provided with thick camel's-hair mats between which the bags holding the meats were placed. The yield of oil was small, a large amount being left in the cake and lost with the meats which went into the hulls.

An important by-product of the old time mills was hull ashes which amounted to about 20 pounds per ton of hulls and were rich

in potash and phosphoric acid. Actually the ash present was several times that recovered. On account of the character of the hulls much of the ash went up chimney. About 1887 it was found that the hulls could be used for fodder and cows have been eating them at increasing prices ever since. At the same time plate presses superseded the old boxes and better work was done in the press rooms. Linter or linter gins were also installed and the short fibers or lint were partially removed from the seed before hulling.

In 1887 the writer started a small laboratory in Chicago for analyzing mill products for the American Cotton Oil Co., which had just come into existence. The results on 244 samples of cake showed an average of 13.55 per cent oil, while 226 samples of meal averaged 12.18 per cent. Hulls were not analyzed but inspected for meats and uncut seed. This was the beginning of mill control work in the industry. It has caused great economies and pointed the way to the use of better machinery. At the present time the meal runs from 6 to 7 per cent oil.

The cotton seed cake has always been either exported as such or ground into meal and used as a cattle food or fertilizer.

One of the latest developments is the extraction of the oil from the cake and meal by solvents. At present prices this is a profitable industry. There is no good reason why solvent extraction should not be applied to the entire meats, cutting out the press room expense and recovering 50 to 60 pounds of oil per ton of seed. If this were done it would have saved last year nearly 500,000 barrels of oil worth about $34,000,000. There is nothing to prevent this development except fear of fire risk and investment of capital. It is a comparatively simple engineering problem which many of us will doubtless live to see accomplished.

Owing to war conditions many oil bearing materials and oils have been brought to this country and handled in the cotton oil mills and refineries. So great has been the variety and quantity of these different oils that it would seem more proper at the present time and in the future to talk of the vegetable industry.

In the time allotted it has been impossible to present more than a sketch of this vast industry, but it is hoped by means of the slides about to be thrown on the screen you may all obtain a more intimate acquaintance with it.

The accompanying collection of photographs, charts and tables are projected on the screen, with the intention of giving the audi-

ence a better mental picture of the cotton oil industry than could be conveyed by means of words alone.

The relative value of different foods is indicated in Fig. 1. In the first column, the percentage of fat in different food materials is shown and in the last column, the number of calories per pound. It will be noticed that the vegetable oils show 4080 calories and are the most concentrated foods on the list.

The relative digestibility of different fats is charted in Fig. 2. This has been worked up from data furnished by the Bureau of Home Economics, based on the careful experimental work of Dr. Holmes. The upper part of the list shows the principal animal fats, the lower part gives the various vegetable fats and oils. The

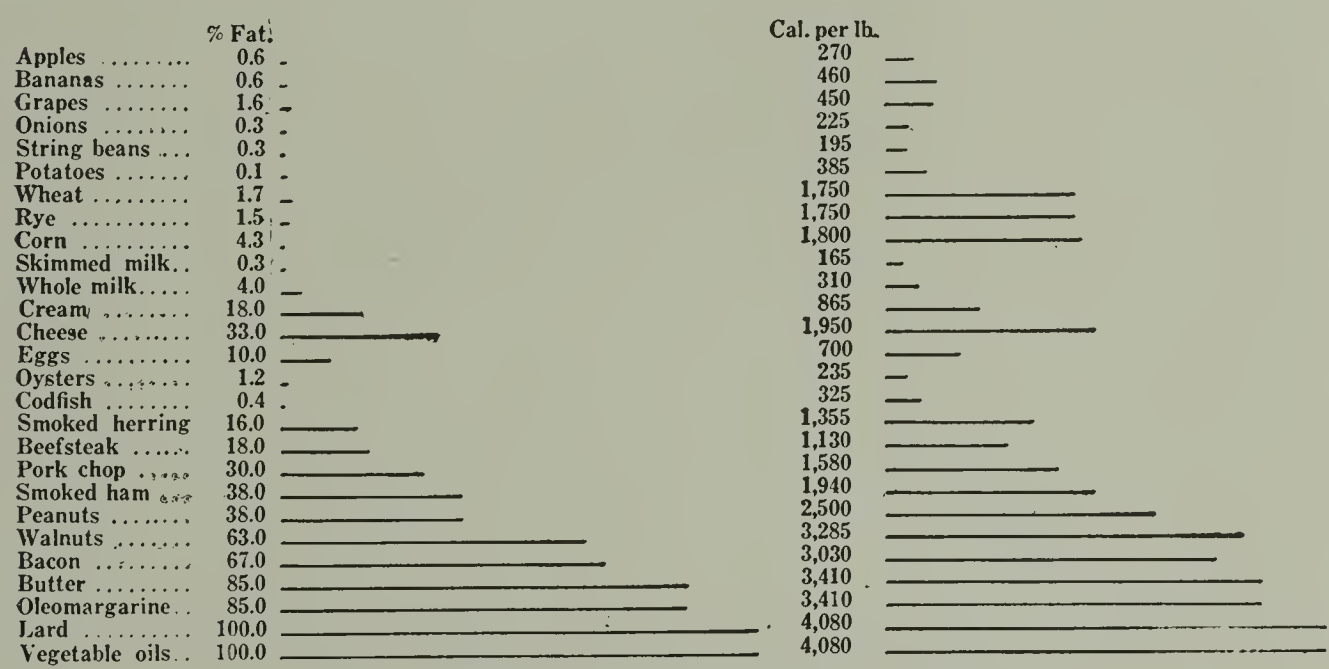


FIG. 1.—Relative Value of Different Foods.

coefficient of digestibility is shown in figures in the first column and graphically in the second. It will be noticed that, with one exception, all the fats shown have coefficients above 90, while the vegetable oils all run between 95 and 100. It is quite evident from this table that the claim frequently made that olive oil is more digestible than cotton seed oil is not substantiated. We must bear in mind, in looking at the next three figures, that we are dealing with statistics. You must remember that Mark Twain used to say, "There are three kinds of lies, namely, lies, damned lies, and statistics"; we can say, however, on governmental authority—and we all believe what our Government tells us—that the statistics I am showing herewith are at least 90 per cent correct.

Fig. 3 shows the relative production of vegetable oils in the

United States as compared with the production of animal fats. Leading the list of the vegetable oils is cotton seed oil, while at the bottom of the list is olive oil, which is hardly visible in the chart. The dotted lines after linseed, cocoanut, peanut and soya bean oils indicate the additional amount of these oils which was imported into the country in 1918. Please pay particular attention to the difference in the production of lard compounds, or *vegetable shortenings,* as they should be called, and lard. It will be noticed that they amount to more than the hog product. Please notice also the great difference between the production of butter fat and oleo

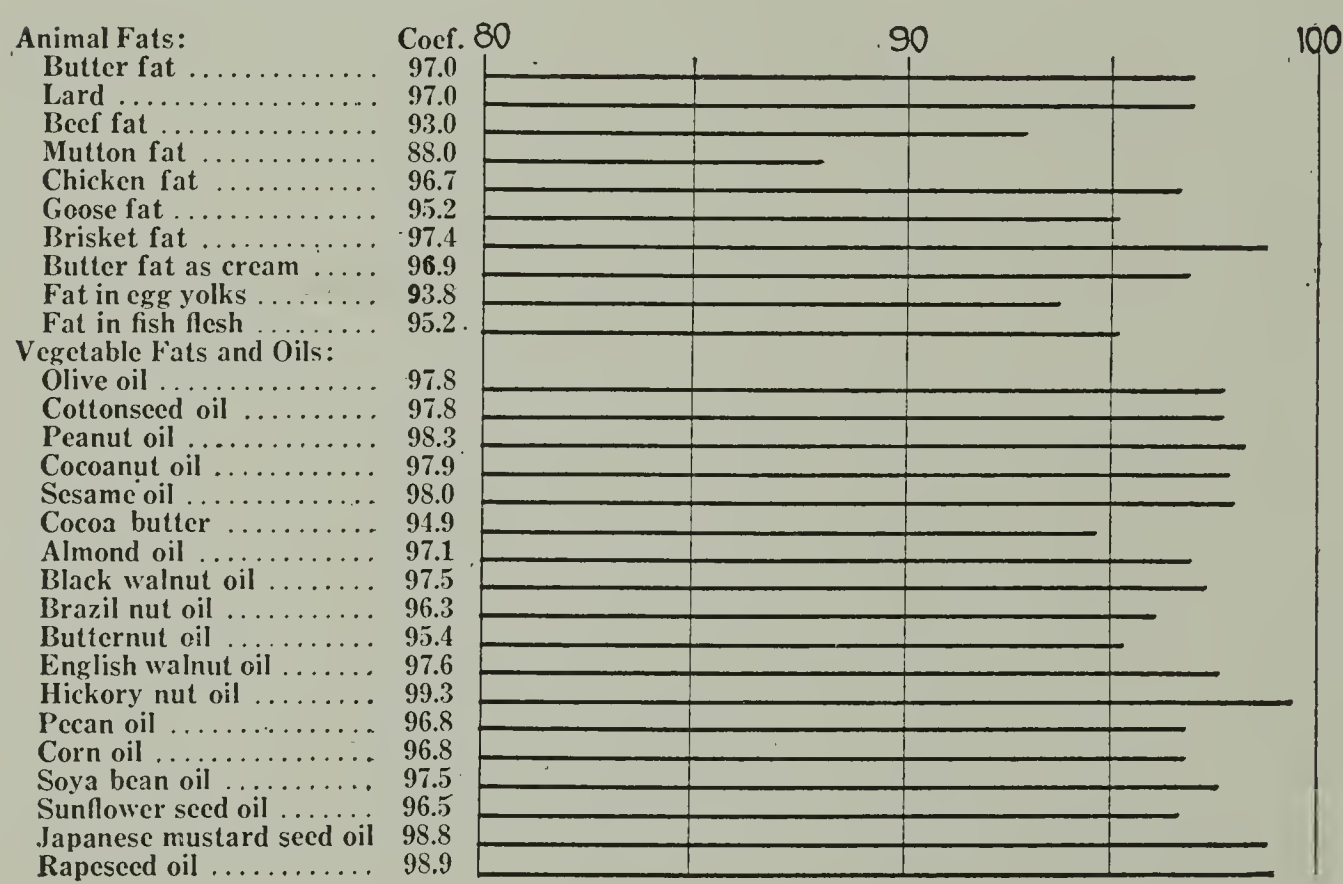


FIG. 2.—Relative Digestibility of Fats.

margarine. With the present high cost of living, there is no question that the latter should be produced in much greater quantities.

The growth of the cotton oil industry is shown in Fig. 4. It will be noted that in 1870 only about 4 per cent of the crop was crushed, while in 1917-1918 about 90 per cent of the crop was crushed. The other curves show the millions of tons of seed and the millions of barrels of oil.

Table I shows the statistics for the cotton oil industry for the year ended July 31, 1919.

TABLE I.—SEED AND PRODUCTS YEAR ENDED JULY 31, 1919

Seed crushed, 4,450,189 tons at $70.00	$311,513,230
Oil made, 1,319,926,000 lb. at $0.17½	230,900,000
Cake and meal, 2,158,77 tons at $50.00	107,939,350
Hulls, 1,124,118 tons at $15.00	16,861,770
Lint, 929,199 bales (500 lb.) at $0.04⅔	21,696,797
Total value mill products	$377,397,917

Plate 1 (p. 23) gives a good view of a cotton field during the picking season. This view was taken some years ago when labor was far more plentiful than at present.

Fig. 5 shows the relation between the market prices of seed and summer yellow oil during the war period.

Plate 2 is an enlarged illustration of a single cotton boll.

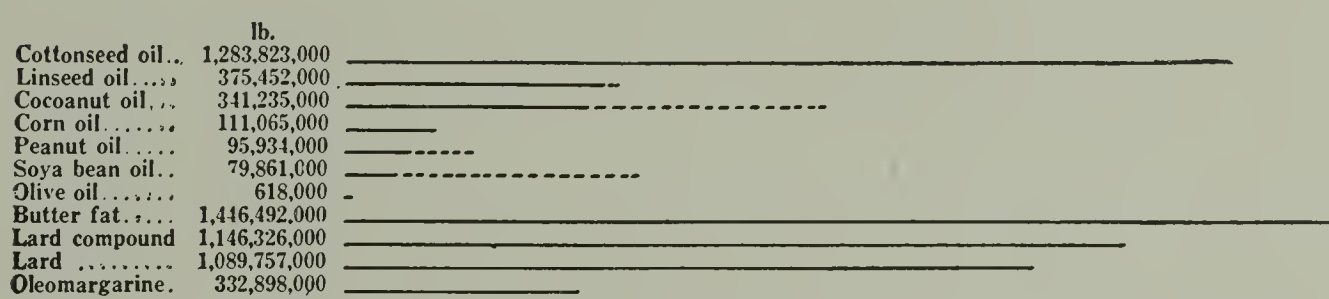


FIG. 3.—Production in United States of Vegetable Oils compared with Animal Fast.

When the cotton is picked, it is hauled to the gin. Plate 3 gives a good idea of a gin during the picking season. Loads of seed cotton are lined up awaiting their turn. It looks like a rather uneconomical system to have a whole lot of teams and men standing idle losing a number of hours' good time waiting for the cotton to go through the gin. This picture, however, was taken some years ago, when labor was not so scarce as it is now.

A good idea of the interior of a gin house is given in Plate 4, showing the gins to the right and the baling press to the left. Ventilating pipes carry off the dust and dirt from the cotton as it is being ginned. The gins consist of a lot of rapidly revolving saws which tear off the fiber from the seed. The fiber and seed are delivered separately, the fiber going into the baling press, and the seed being delivered to the mills. Plate 5 shows how seed looks in a small pile. It represents about a handful of seed.

Fig. 6 shows two sections of the cotton seed. The little black dots seen throughout the seed contain a resinous coloring matter

called "gossypol," which is responsible for the dark color in the crude oil. The seeds are really small nuts about ⅜ in. long and about $^3/_{16}$ in. in diameter. They are surrounded by a leathery shell or hull, from which grow the cotton fibers. The gin always leaves a certain amount of fiber adhering to the hull. Fig. 7 shows an enlarged section of the cotton seed, portraying particularly the structure of the hull, as well as the kernel.

Table II shows analyses of cotton seed from Georgia and

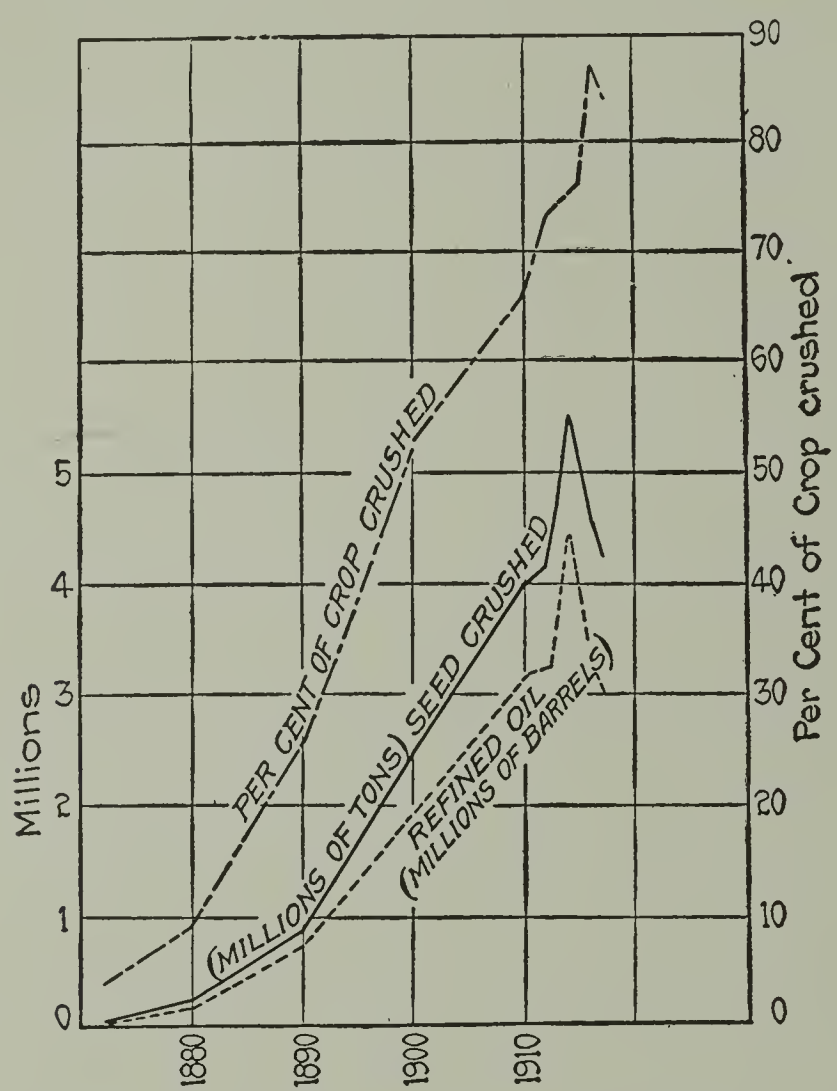
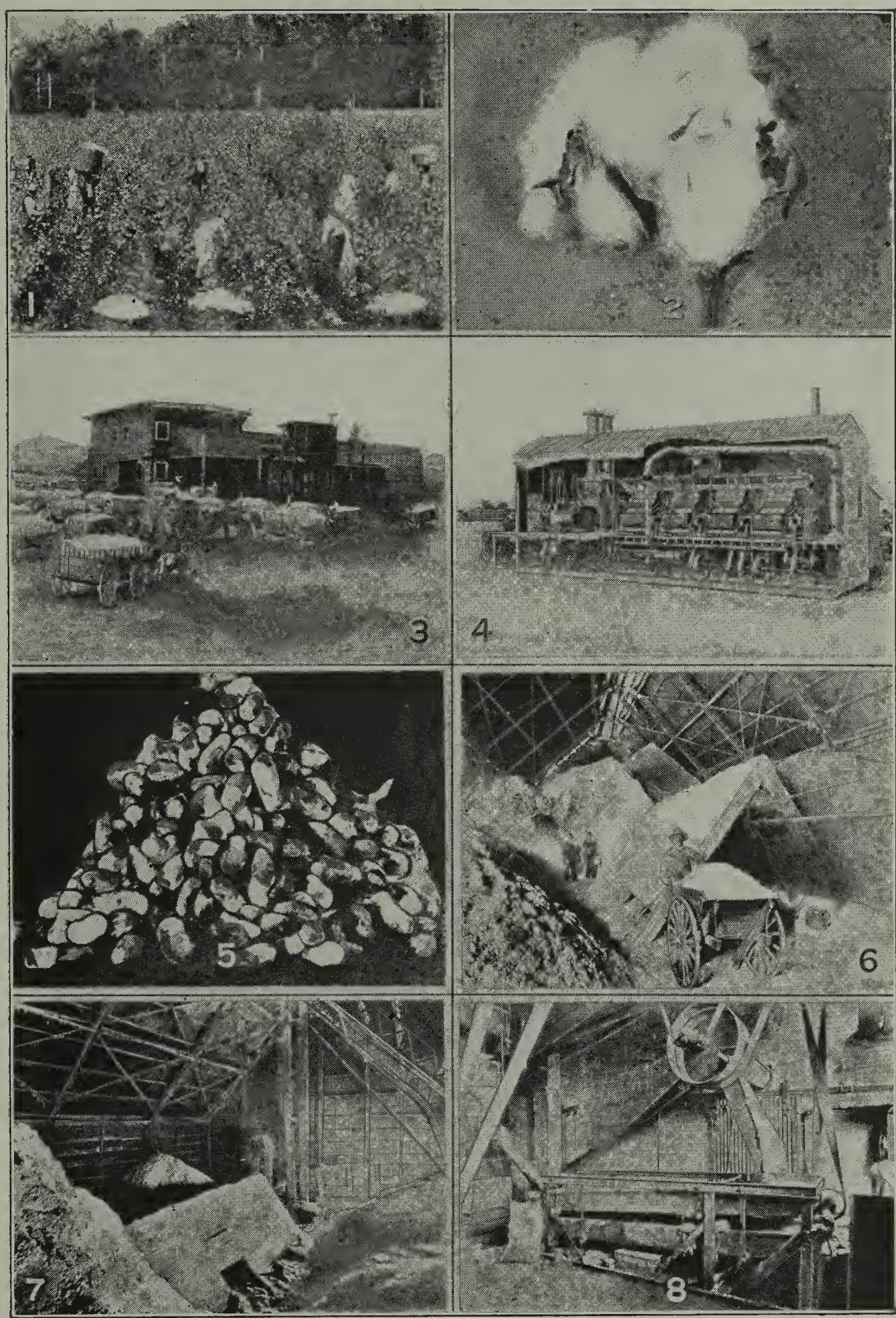


FIG. 4.—Growth of the Cotton Oil Industry.

Texas. Please notice the big variation in the percentage of oil in the meats, that in Georgia being very much higher than in the Texas seed, while the ammonia and protein are much higher in the Texas than in the Georgia seed.

When the seed reach the mill, they are first unloaded from the cars or wagons and delivered to the seed house. This seed house, Plate 6, is for a small mill. Ordinarily, at the bottom of the tunnel is a conveyor, into which the seed is shovelled. In a small mill, however, a conveyor is not necessary, as the seed can



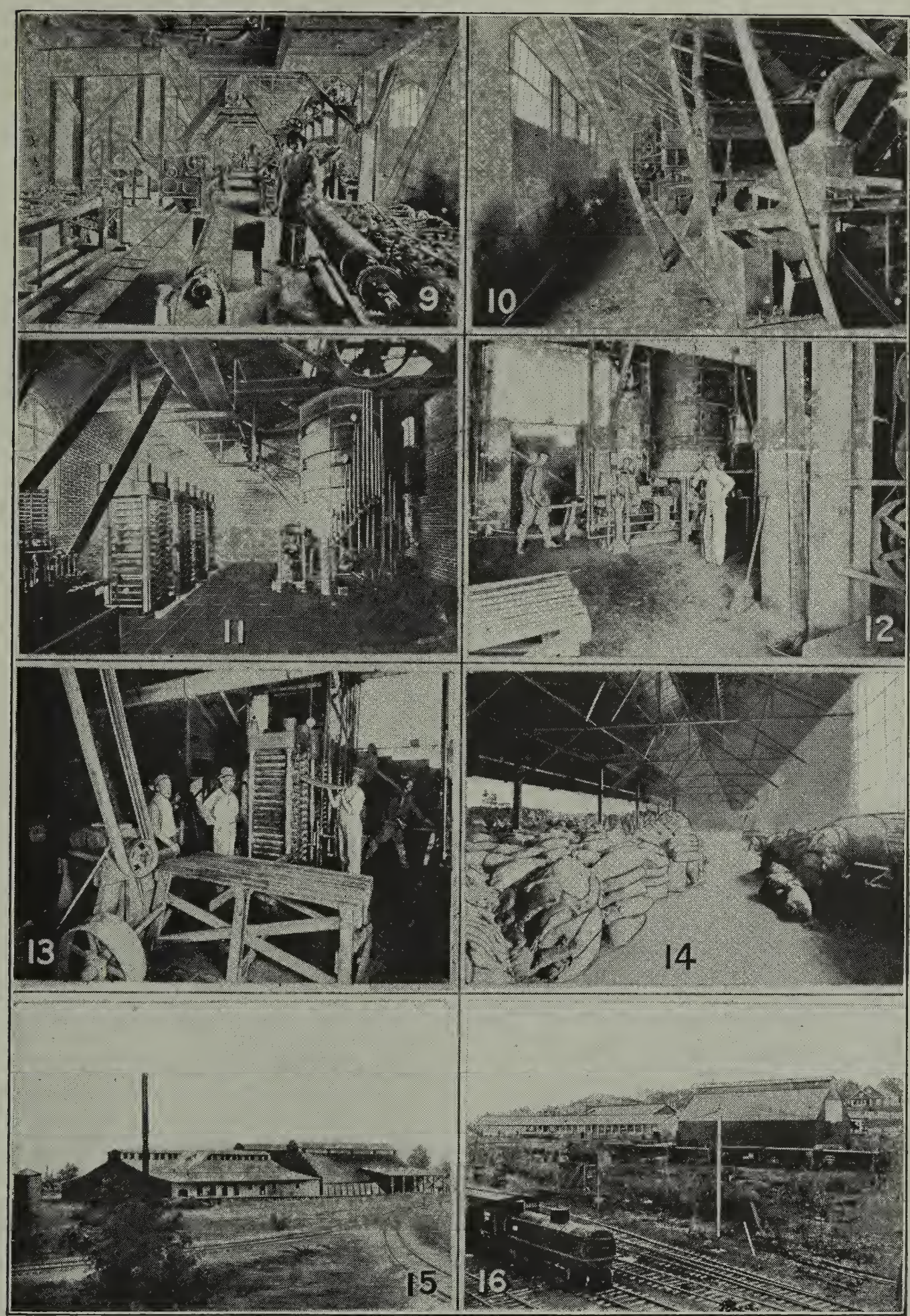
PLATES 1 TO 8.

TABLE II.—COTTONSEED ANALYSES

	Georgia, Per Cent.	Texas, Per Cent.
Hulls	45.00	47.00
Meats	55.00	53.00
Oil in meats	37.00	31.20
NH_3 in meats	6.60	8.40
Protein in meats	36.99	43.50
Mill yields per ton of seed:	Pound.	Pound.
Cake	1,010.00*	1,056.00*
Oil	337.50	256.00
Linters	155.00	145.00
Hulls	375.00	515.00
Loss	123.00	100.00
* NH_3 in cake, per cent	7.16	8.00

be put into carts and carried from the tunnel when the house is full. It is then emptied into the elevator boat at the end of the building, as shown in Plate 7.

A shaking screen which separates the seed from the bolls, stones, sticks, etc., is shown in Plate 8. The trash is collected in a bag at one end of the screen, while the clean seed is fed to a conveyor, which carries the seed to the linters, shown in the background of Plate 9. These linters are really gins which remove the lint remaining on the seed. The quality of the lint depends on the amount removed per ton of seed. During the war, the Government demanded the largest possible output, and it was the practice to remove 150 pounds of lint per ton of seed. This lint contained considerable cut hull and trash. Good practice at the present time removes 80 to 100 pounds, while, if a superior quality is desired, two cuts are made: the first cut taking off 25 to 40 pounds, while the second cut yields the inferior lint, as much being removed as may be desired. The linted seed next passes through the hullers, which chop the seed up fine. The mixture of hulls and meats is then passed through a series of screens and reels, which separate the hulls from the meats. Plate 10 gives a good idea of the appearance of the separating machinery in a modern mill.



PLATES 9 TO 16.

Plate 11 shows a picture of a model press room, which looks as though it has been cleaned up for shutting down the mill for an indefinite period. It is altogether too clean for a mill in actual operation!

Plate 12 was taken while the mill was working. In the center is shown a French heater, where the meats are cooked, while, to the left of it, is shown the cake former, where the cooked meats are formed up into cakes before going to the presses. The broom in the foreground is a guarantee that this picture was not fixed up for the photographer.

Another view in the same press room is given in Plate 13,

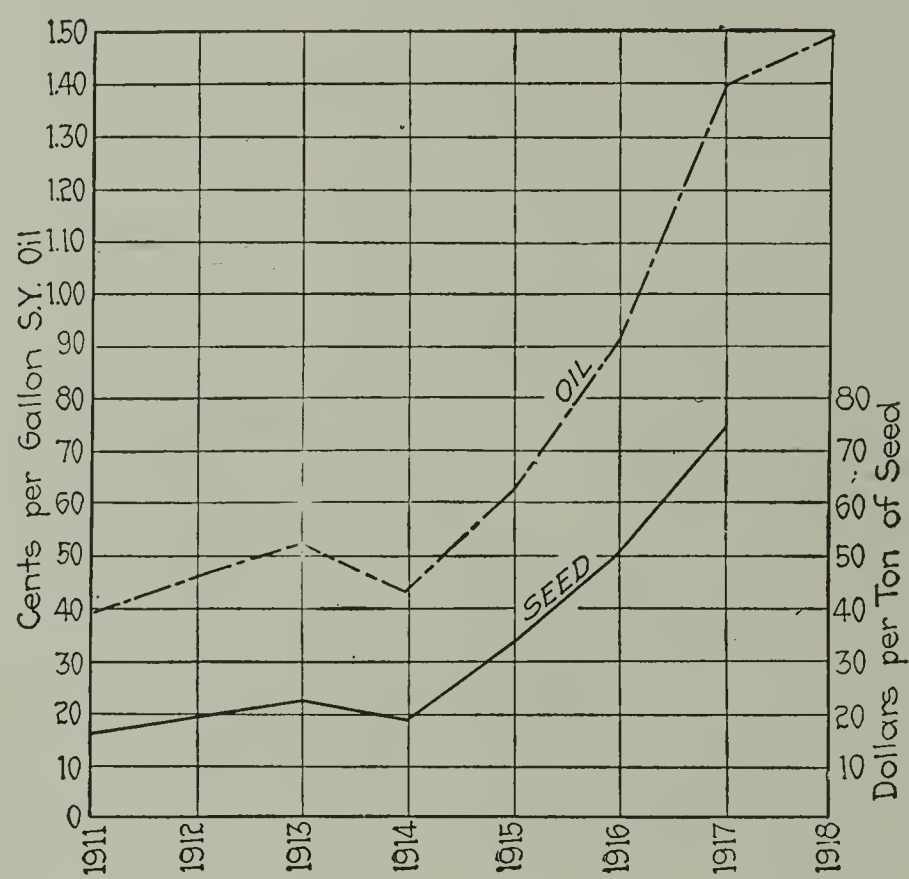
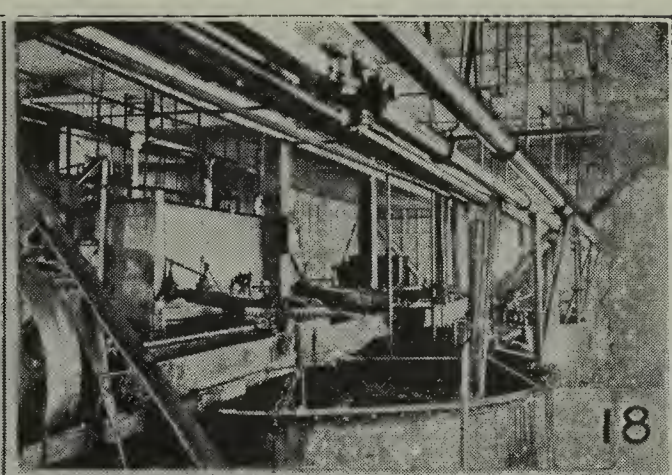
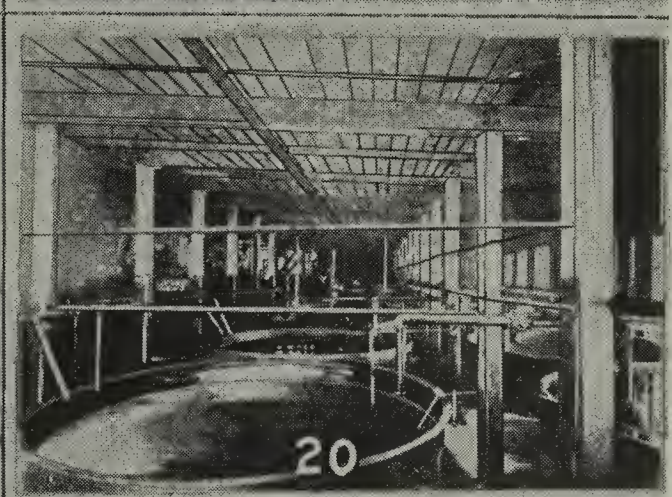


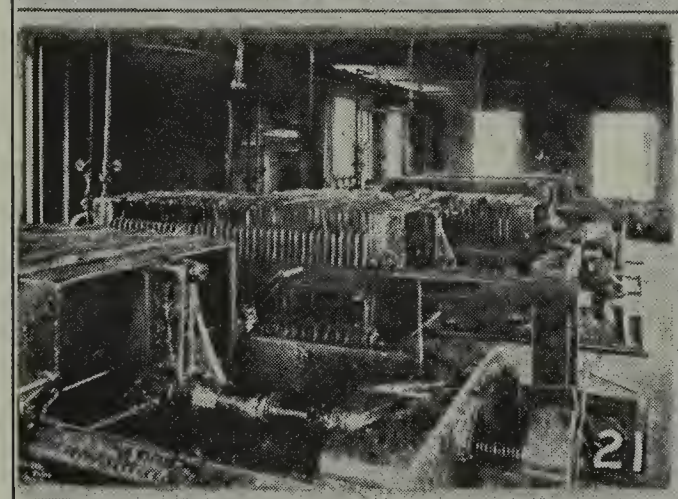
FIG. 5.—Market Values of Seed and Oil During the War Period.

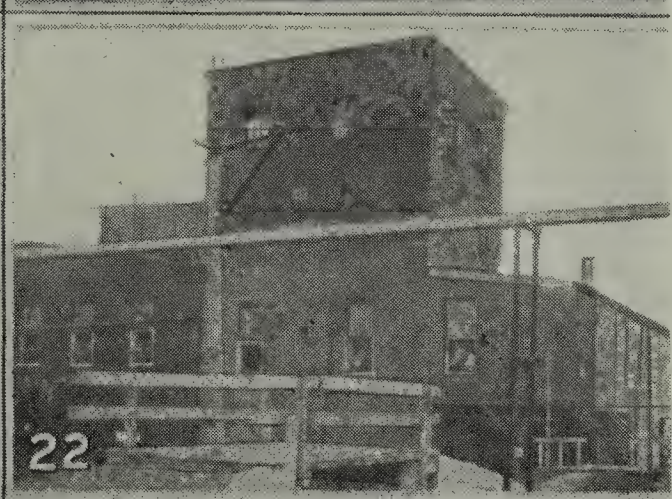
showing the working of the presses. These presses make two or three turns an hour. In figuring the capacity of the mill, it is common practice to figure one ton of seed for each press plate for 24 hours.

Plate 14 shows the meal shed, where the cake, after being taken from the presses and ground, is piled up in bags ready for shipment. Plate 15 is a typical illustration of an old-time oil mill. At one end is the mill proper with the boiler and engine room, next to which is the press room, and, beyond the linters, a separating machine, while at the further end is shown the seed house, on one









PLATES 17 TO 24.

side, and the hull and meal houses on the other. Plate 16 is a modern mill. The large building to the right is the seed house, and the low building to the left is the mill proper. This mill is operated mostly by electricity.

The latest thing in oil mill construction is illustrated in Plate 17. It is the New South Oil Mill at Helena, Ark. The concrete cylindrical tanks are used for storing the seed, and, according to reports, there has been no trouble so far this season from the seed heating or otherwise deteriorating.

With the reservations made regarding statistics, Fig. 8, compiled partly from the results given by D. A. Tompkins in his work

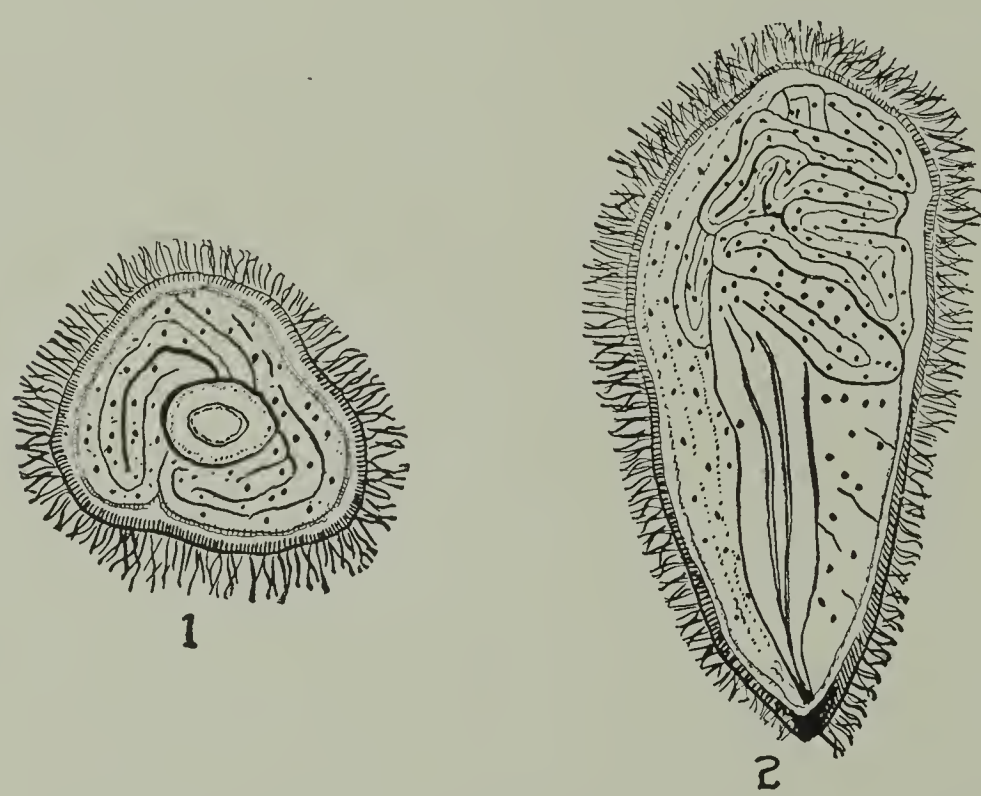


Fig. 6.—Two Sections of the Cottonseed.

on "Cotton and Cotton Seed Oil," published about 1901, shows the improvement made in cotton seed milling from 1875 to 1920. In the early days of the industry, the seed was considered to be half hulls and half meats. Not much attention was paid to waste, and, besides, the gins left a great deal more fiber on the hulls than they do at present. In 1875, it will be noticed, the yield from a ton of seed was 225 pounds of oil and 675 pounds of meal. At that time, the hulls were burned under the boilers and not much attention paid to them. The large proportion of oil left in the meal will be noticed. In 1900 a much larger output of oil is shown, while account is made of the lint and loss, amount of hulls being

the same. In 1920 we would have a quite different yield, only 60 pounds of oil being left behind in the meal, which, it will be noticed, amounts to 980 pounds altogether. It will also be noticed there is a large yield of lint, while the hulls are shrunk to 490 pounds. The rest of them are something like the salesman's overcoat and the expense account; in this case, the missing hulls have disappeared in the meal.

Fig. 9 shows the results of milling a ton of seed for the year ended July 31, 1919. The crude oil, as it comes from the mill, is very dark in color, averaging about that of claret, but with a

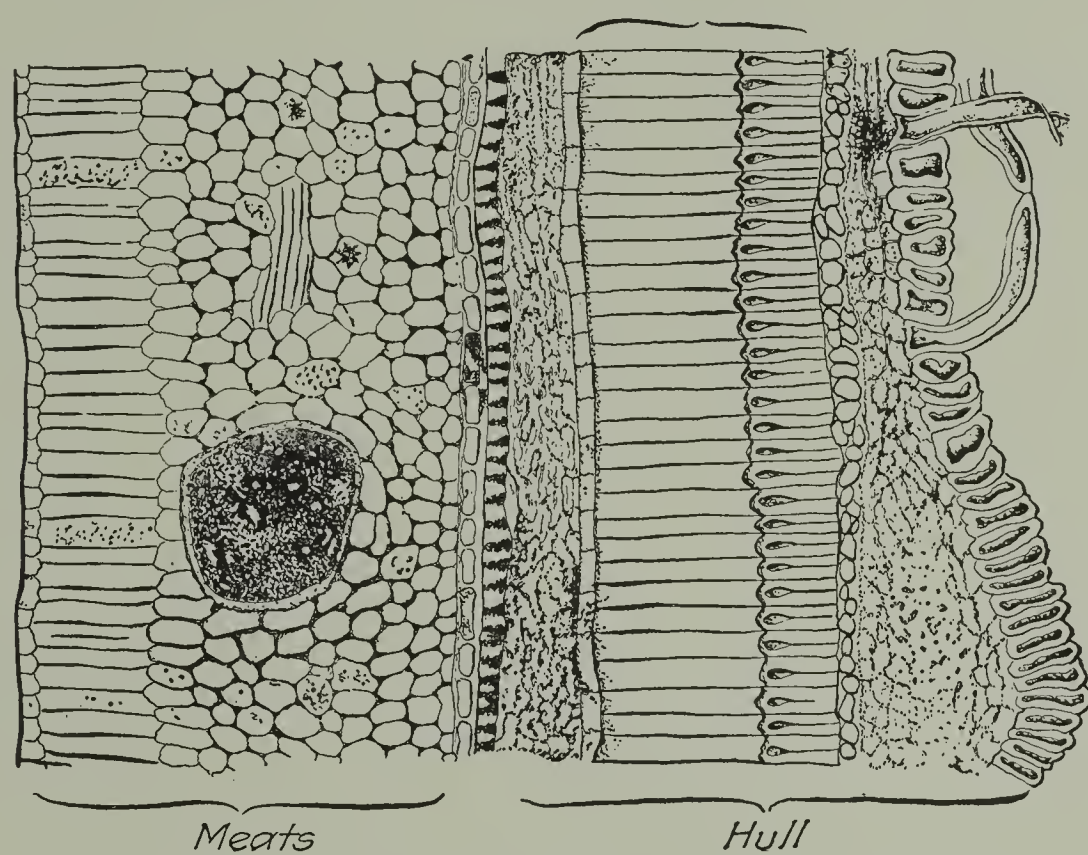


Fig. 7.—Enlarged Section of the Cottonseed.

somewhat brownish cast. When it reaches the refinery, it is pumped into refining tanks shown in Plate 18, holding from 60,000 to 120,000 pounds. These are provided with agitating machinery, and also large steam coils for heating the oil rapidly. Above the tanks are smaller ones for weighing or measuring in the caustic soda required for the refining. The proper amount of caustic is run into the oil, while it is being agitated, and, after the agitation has continued for some little time, small flakes begin to form. The machinery is then slowed down and heat applied. The flakes grow larger and larger, and owing to the decreased density of the oil, on account of the heating, the flakes soon begin to flow, and when in

the right condition for settling rapidly, the steam and agitation are shut off, and the tanks are allowed to settle, preferably for 24 hours. Plate 19 represents the bottom of the refining kettle, provided with a cone and heating jacket for melting out the soap stock after the oil has been pumped off. The light yellow oil is pumped off into large tanks, such as are shown in Plate 20, where it is allowed to settle and drop out the fine soap, which is still suspended therein.

Fig. 10 shows the relation between free fatty acids in the crude oil and refining losses. These curves were plotted from refinings made all through the season and can be considered as typical. The

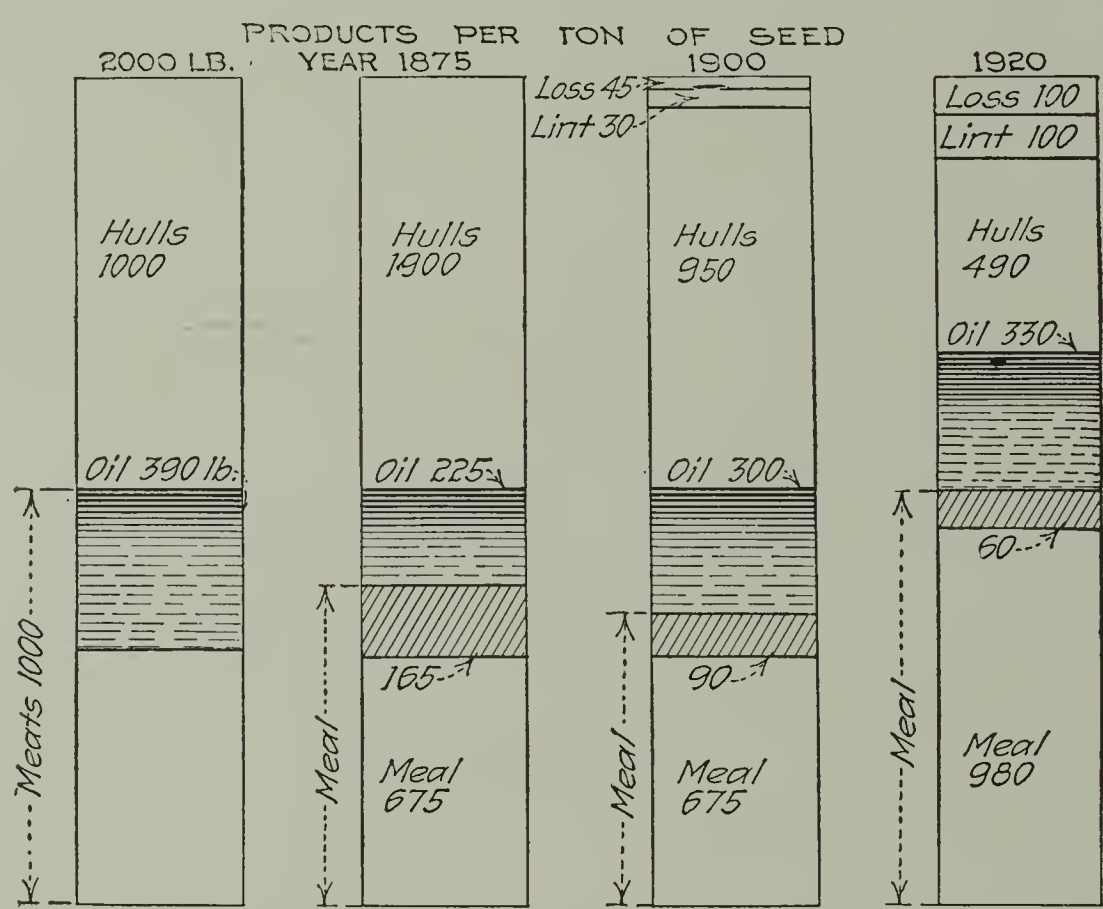
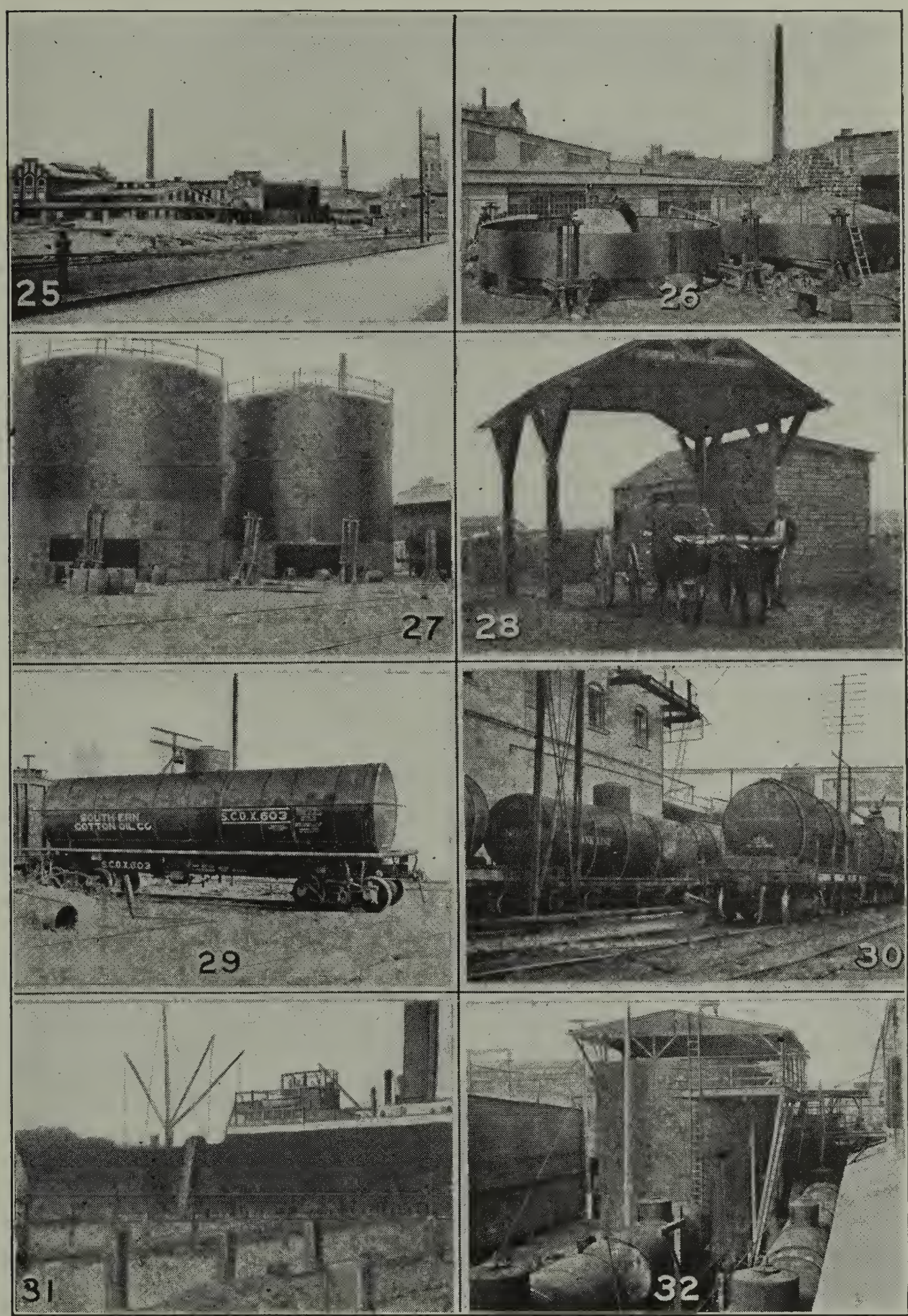


Fig. 8.—Improvement in Cottonseed Milling, 1875–1920.

settled oil is transferred to kettles with heating coils and agitating machinery where a small percentage of fuller's earth is added and well mixed with the hot oil, which is next pumped through filter presses, as shown in Plate 21. This removes the fuller's earth and delivers the clear white oil, which next goes to the deodorizing kettles, after which it comes out almost water white.

The first refineries constructed in this country were mostly frame buildings, which were sufficient to protect the tanks and machinery from the weather. Plate 22 shows one of the oldest plants of the Southern Cotton Oil Co., located at Gretna, La.

Plate 23 shows the refinery of the Southern Cotton Oil Co. at



PLATES 25 TO 32.

Savannah, taken about 12 years ago. The plant has been greatly expanded since that time.

Another old plant, built about 1887 by the Olivers at Charlotte, is shown in Plate 24.

With such a demand for the fine quality of oil produced in America, it was necessary to put up plants in Europe. A plant which was in successful operation up to 1916 in Germany is shown on Plate 25. This plant rejoices in the euphonious name of the Wesson Gesellschaft für Deutschland mit Beschrenkene Helftung.

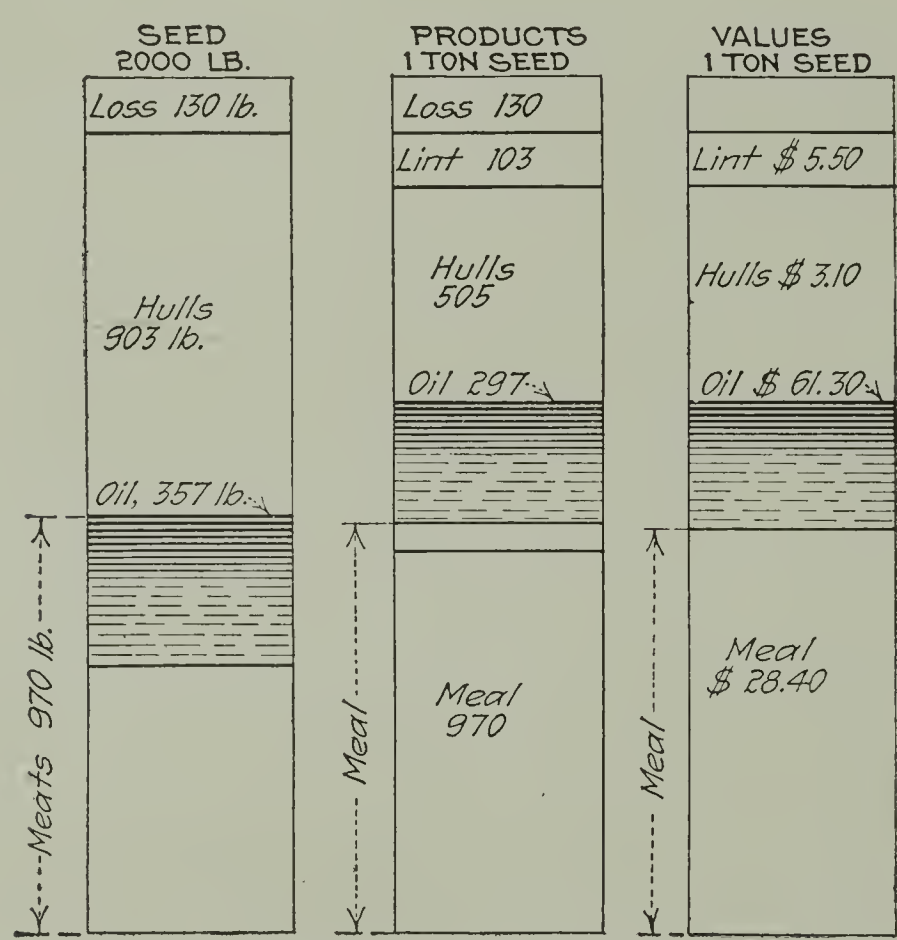


Fig. 9.—Results of Milling a Ton of Seed.

At the present time, it has somewhat beschrenked. It is of interest in this connection to show how storage tanks are constructed in Germany. The practice prior to the war was to first lay down the bottom of the tank, then set up the top ring on jacks and build the roof, as shown in Plate 26. The tank was gradually raised and new rings put on from the bottom until the bottom ring was finally put on and closed up, as shown in Plate 27. This saved the expense of scaffolding, and, at the same time, kept the men on the ground.

Transportation is an important feature in all industries. It is

quite common around oil mills, even to-day, to see ox teams, as shown in Plate 28. On the face of it, these teams appear rather slow and possibly expensive transportation, but when it is considered that old scrawny steers can be bought very cheap and fattened on meal and hulls at the same time they are making themselves useful as beasts of burden, it is not such a bad proposition as appears on its face. In the early days of the industry, the crude oil was shipped from the mills to refineries in the North in all kinds of cooperage. The speaker has frequently seen lighter loads playing around New York harbor which looked like a package of firecrackers. The barrels, on examination, are found to have been used for kerosene, naphtha, lubricating oils, varnish, whiskey, and

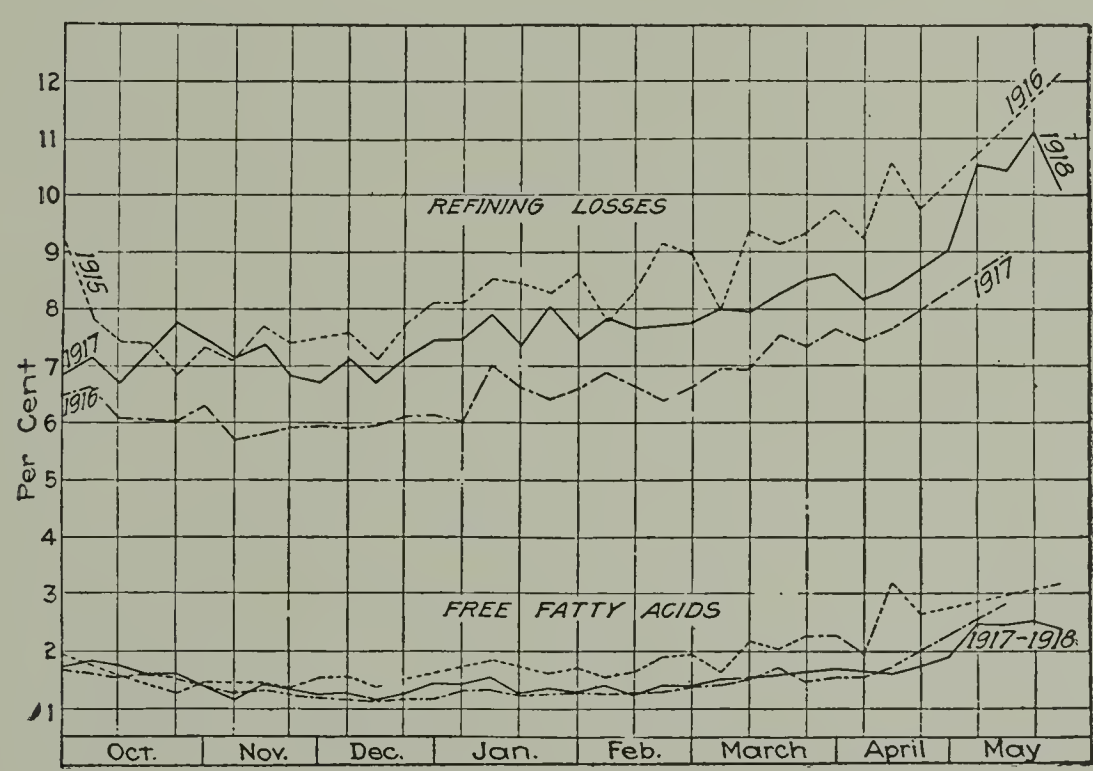


Fig. 10.—Relation between Free Fatty Acids in Crude Oil and Refining Losses.

what not. In this connection, I remember at the old plant of the N. K. Fairbank Co., 14th St., New York, the night man emptied a lot of oil barrels into a tank to be refined the next morning. The oil in the tank had a flavor never before noticed in crude cotton seed oil. It was found that by mistake a barrel of whiskey had been emptied along with the oil, and there was great lamentation on the part of the steamship company, as well as the men who committed this gross carelessness. Nowadays, crude oil is almost entirely handled in large tank cars, holding as much as 250 barrels of 400 pounds each. Such a car is shown in Plate 29.

Plate 30 shows the tracks at a modern refinery filled with tank

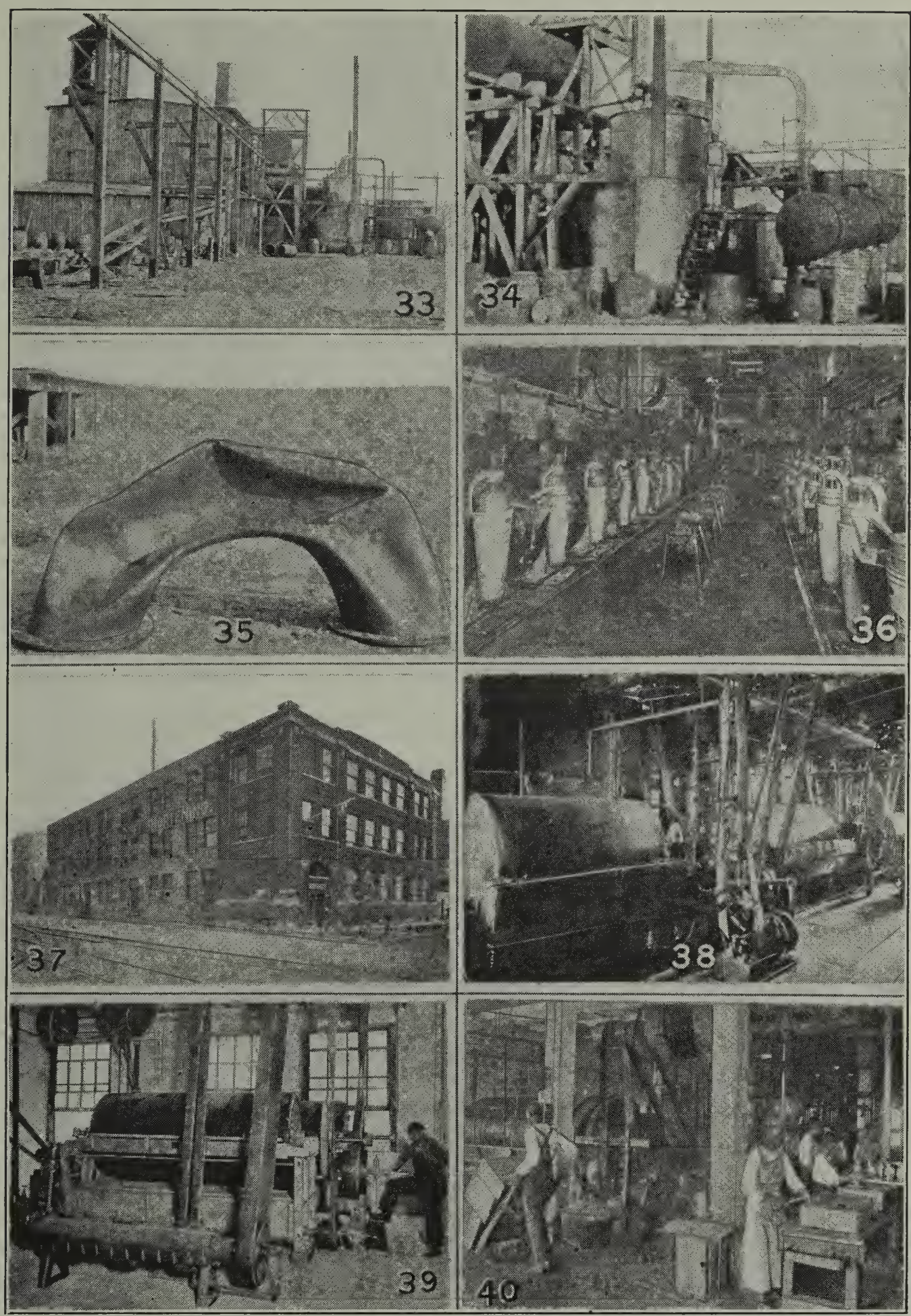
cars ready for unloading. For European shipment, the oil has to be shipped in carefully prepared barrels. Plate 31 shows a steamer being loaded for Europe at our New Orleans refinery.

In a talk on the cotton oil industry, sight must not be lost of the soap stock. The early refineries used to boil this material up with caustic soda and convert it into a soft yellow soap, which was used more or less by woolen mills. This soap was also boiled down on strong brine until it carried about 30 per cent of water, which made it suitable for export to England, where large quantities were used. About 1886, it was found that by mixing the soap with soda ash, it could be made into very useful washing powder, which has since been advertised extensively by means of the Gold Dust Twins. In the plant of the Southern Cotton Oil Co. at Savannah, the speaker once needed some large soap kettles in a hurry, so he removed the covers from some storage tanks, lagged outside with wood, built a roof over the tops of the tanks, and these were used for some years quite successfully. As these tanks are somewhat of a novelty in the way of soap kettles a picture is shown in Plate 32.

Plates 33 and 34 show the first plant put up in Savannah for the distillation of the black grease made by decomposing the cotton seed soap stock with sulphuric acid. It was more or less of a temporary affair, which met with a sad accident and burned down a couple of years after it was put up.

On account of more or less destructive distillation taking place, owing to the impurities of the black grease, the vapors in the stills were very destructive to copper. Plate 35 shows a copper connection between two of the condensers after it collapsed one day and scared the operators nearly to death.

The modern way of handling soap stock is by means of the Sharples super-centrifuges, which are shown in battery in Plate 36. These recover between 60 and 70 per cent of the entrained oil from the soap stock and reduce the refining loss about 1 per cent. Plate 37 shows one of our latest vegetable shortening plants, located in Chicago. In the manufacturing of vegetable shortening, the oil and hard fat, which, in these days, is almost exclusively hydrogenized cotton seed oil, are mixed in large tanks and then passed over revolving cylinders through which brine from an ice machine is circulated. Plates 38 and 39 show these cylinders in operation. The lard is fed into a trough in which the cylinders set and is chilled on the surface of the cylinder as it revolves. Knives scrape



PLATES 33 TO 40.

the chilled lard from the surface of the cylinder, in such a way that it continually drops through into a trough in which there is a rapidly revolving shaft covered with blades which break up all the lumps and beat a certain amount of air into the lard. Pumps take the shortening, which is of a creamy consistency, from this trough and pump it directly into the packages.

Plate 40 shows the filling room in the Savannah plant, taken about 15 years ago, and Plate 41 shows another view in the packing room. Please notice the large amount of labor present, and also notice that it consists almost entirely of men. Another view of the same work at that time is given in Plate 42, and Plate 43 shows the filling of tubs and large packages. Plate 44 shows the way the product was loaded into cars about 12 or 15 years ago.

During the last few years, automatic machinery has been installed and in the words of the song, we "let the women do the work." In Plate 45 girls are shown filling large size cans. These are handled altogether by automatic machinery, as is shown in Plate 46, which is a picture of the same filling room shown on a preceding plate. Notice the few hands present and the neat orderly character of the work.

Other views of the same room are given in Plates 47 and 51 and show one of the automatic carriers for handling filled tins. Plate 48 shows the arrangement for filling and automatically soldering oil in cans.

An automatic carrier for loading tubs into cars is shown in Plate 49. This is on the shipping platform and will serve cars along a platform 200 or 300 feet in length, the only labor needed being to put the tubs on to the carrier and properly pile them in the cars where they are delivered.

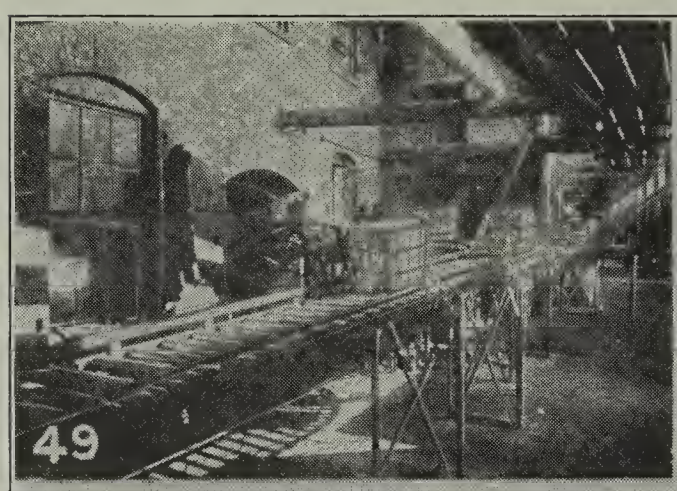
Plate 52 shows one of the early chemists already mentioned, and the kind of an outfit used by him for testing his crude oil to see if it was refined properly. This gentleman now occupies an exalted position with one of the large companies.

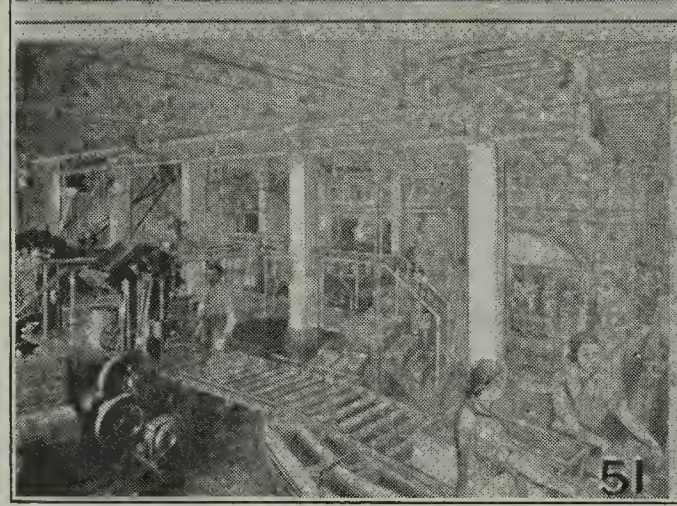
Plate 50 is another laboratory view, and shows a young chemist grading oil samples for color. In the early days of a certain refinery I know of there was a colored assistant for nearly every white man in the refinery.

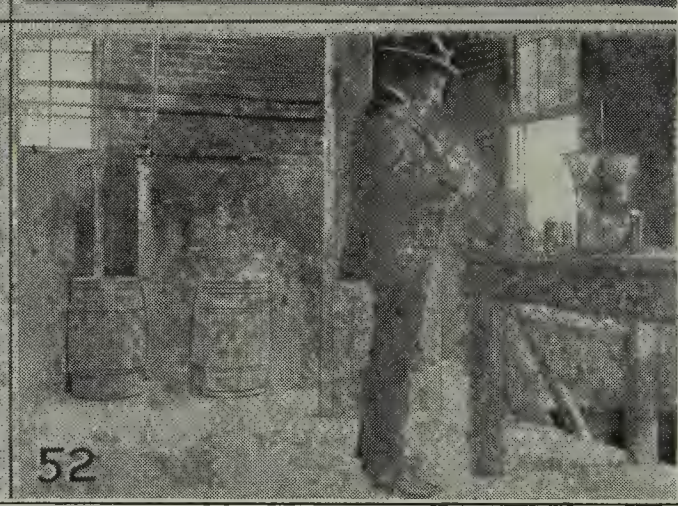
A great deal has been said of the wonderful virtues of highly refined cotton seed oil. Eighteen years ago I made some experiments with a certain well-known brand of oil, which has been ex-

PLATES 41 TO 48.

tensively advertised, believing that the butter fat of cream could be replaced by the oil and successfully worked into ice cream. An experiment tried in my laboratory seemed to prove the theory to be correct.







PLATES 49 TO 52.

ECONOMIC AND MINERAL RESOURCES OF THE SOUTH OF INTEREST TO CHEMICAL MANUFACTURERS

By RICHARD K. MEADE

Read at the Savannah meeting, Dec. 3, 1919

Until the closing decade of the past century, the South was almost entirely an agricultural community. The cotton crop was sent to New England to be woven into cloth. The hides from Texas cattle were sometimes tanned in southern yards but the shodding of southern feet was left to New England. Some iron was smelted. Some coke was made and a little gold was mined. For the most part, however, the South with a vast store of untouched mineral wealth remained an agricultural community until the beginning of the present century.

The last three decades, however, have seen an important change in the economic situation of the south. It still produces more than half the total farm products of the country and agriculture furnishes even now the means of livelihood for most of its people, but I am sure that those of you who have traveled through from the North have seen evidences of its coming development into an important manufacturing center. The numerous cotton mill settlements which you have seen in the Carolinas are only a part of this development, however. Had your train passed through the beautiful Appalachian section of the South you would have seen the smoking stacks of many chemical and metallurgical plants also. This section of the country comprising western Virginia and North Carolina, eastern Tennessee, northwestern Georgia and northern Alabama, is, I believe, unequaled for the extent and diversity of its mineral wealth.

We already have in the South the two largest plants in the world for the manufacture of sulphuric acid and the second largest sugar refinery. By far the greatest quantity of acid phosphate and mixed fertilizer is made in the South. The greater part of the cement needed by the South can now be made in its plants and

lime from the Virginias and Maryland not only supplies these States but also many of the chemical plants at Jersey City and Niagara Falls. Much of the iron and steel used in the South comes from the Birmingham district and no doubt more would come from this section but for reasons which are without the province of either metallurgy or economics.

Economists have attributed the wealth of Great Britain to her abundant stores of coal, iron ore and limestone. The southern coal reserve is more than two and one-half times that of Great Britain. Her iron ore reserve three times as great and her limestone beds beyond comparison. To heighten the advantage, the South has the finest deposit of sulphur in the world, an inexhaustible supply of salt, much oil, natural gas and many minerals.

In spite of this plethora of mineral wealth, however, the entire sixteen Southern States, including Maryland, West Virginia, Kentucky, Missouri and Oklahoma, have less capital invested in manufacturing than have the two States of Illinois and Ohio. Massachusettes, a commonwealth without marked resources in the way of fuels, minerals, agricultural or forest resources, has more money invested in manufacturing within her boundaries than have the six Southern States which are richest in mineral wealth.

If the South is to reap the full benefit of her vast resources she must develop much farther along manufacturing lines. It is not enough for the South to mine her ores, to cut her timber, to grow her crops, she should so market these that they will represent the greatest value. A ton of limestone and a little less of coke represent a value of only a few dollars but the 2300 pounds of carbide into which they may be made by employing water at present going to waste is valued at something like $100.

In spite of the progress which has been made in the South during the past years, I prefer to regard it as a land of great future possibilities in manufacturing rather than as one in which this has in any way been achieved. I am, therefore, presenting for the consideration of the Institute some of the advantages which this section has to offer for the location of chemical plants.

The chief factors which determine the location of any manufacturing plant, where this is done after scientific study rather than the desire or pleasure of the owners, are the ability to obtain cheaply suitable raw materials, labor and fuel and to reach the market on a competitive basis. Added to the above are, of course,

a host of minor considerations such as low tax rates, and in the case of special industries, climate, water supply, laws which will permit of the disposing of waste material without hindrance, etc.

Fuel.

The South to-day mines about one-quarter of the coal output of the country and manufactures about one-sixth of the coke. The southern coal area is twice that of Europe and extends over 88,000 square miles. It is estimated to contain approximately three-fourths of the coking coal of the nation. For the most part, this coal area lies nearest the region of greatest mineral wealth, namely along the slopes of the Appalachian Mountains and hence relatively cheap fuel is available throughout much of the region to which chemical manufacturers are most likely to be drawn. All of the coal in this section of the South is high-grade bituminous. For those requiring a special grade of fuel, coals low in phosphorus, sulphur and ash are generally available.

In addition to this area of bituminous coal, there are over 80,000 square miles of territory believed to contain lignite. The future potentialities of this field are believed to be enormous, but its present value is small because better fuel is easily available. The utilization of this lignite is a problem for chemical engineering.

Coke is made pretty generally throughout the territory and there are some by-product coke ovens located chiefly at Sparrows Point, Md., and in the Birmingham district from which sulphate of ammonia, benzol, toluol, etc., can be obtained.

I am giving below some of my analyses of southern coals. All of these samples were drawn from cars and do not represent simply selected lumps of coal.

Location.	Moisture.	Vol. Comb. Matter.	Fixed Carbon.	Ash.	Sulphur.	B.t.u. per Poud.
Georges Creek, Md.	2.10	17.14	72.46	8.30	1.02	13,972
Pocahontas, Va.....	1.25	17.35	74.28	7.12	0.80	14,210
New River, W. Va..	1.50	22.02	70.40	6.08	0.63	
Clinchfield, Va.....	0.95	36.95	55.95	7.10	0.60	14,560
Wilder, Tenn.....	2.26	34.10	60.12	12.52	2.40	
Bell Co., Kentucky..	3.21	38.70	49.30	8.79	1.16	14,109
Mary Lee, Ala.....	2.50	27.10	59.38	11.02	0.82	
Mendota, Mo.....	12.18	27.16	36.12	23.54	3.75	

The southern oil fields lie mostly in West Virginia, Louisiana, Texas and Oklahoma. It is estimated that these oil fields have a possible production of more than four billion barrels of petroleum and at the present time do furnish fully a third of the world's supply of this. The Gulf States can, of course, be supplied with oil very easily from the Mexican field also.

It is generally recognized that the asphaltic oils of the Gulf Coast are more easily broken up by chemical reagents than are the paraffin oils of the North, and as a beginning chemical research has found it comparatively easy to make from them such important technical compounds as carbon tetrachloride, chloroform, chloral, etc. Where else in the world do we find such a wealth of chemical reagents, so close at hand—salt, sulphur, lime and cheap power from gas. This line of research and its practical application should open up a wonderful chemical industry.

Natural gas occurs in numerous localities in the South and West Virginia was the birthplace of the industry in America. The chief fields are in West Virginia, Louisiana, Oklahoma and Texas. The two most promising fields so far as industrial users are concerned are the Caddo gas fields in northern Louisiana and the Corpus Christi district in Texas. The Caddo gas is 95% methane and the geological indications are that a supply of long duration is obtainable there. The principal manufacturing city in this district is Shreveport, where the gas is obtainable. A new field of interest is the Henryetta district of Oklahoma, where the present price is only 6 to 8c. per M ft. with 400,000,000 ft. at present available.

I am giving below an analysis of the Caddo gas.

Methane	95.00%
Carbon dioxide	2.34
Nitrogen	2.55
Hydrogen sulphide	0.01
Calories per cubic meter	8,168
B.t.u. per cubic foot	918

Power.

The National Geological Survey has estimated that the water power in the streams of the Southern States amount to a minimum of nearly 5,000,000 horse power and a maximum of over 9,000,000 horse power. The water power developments now in operation

amount to about 1,000,000 horse power or a development of about one-fifth of the possible minimum flow. The Southern Power Co. already has developed nearly a third of a million horse power and three others have over one hundred thousand horse power available.

The survey places the available power in the headwaters of the Appalachian Mountains at 2,800,000 horse power. This region has the highest rainfall in the United States, the topography is ideal for the development of low head power stations and the climatic conditions are favorable to the maintenance of transmission lines. This region is also that of greatest mineral wealth, iron, coal and limestone all abound there and therefore the one most suited to the establishment of Electrochemical industries. (The location of mineral deposits in this district is given further on in this paper.)

The water power available in the various southern streams is shown by the following table:

RESOURCES OF POWER IN SOUTHERN STREAMS

Rivers.	Drainage Area, Square Miles.	Estimated Minimum.	Horsepower Maximum.
Potomac	14,300	176,000	462,000
James	10,400	196,000	300,000
Chowan	5,000	5,100	10,100
Roanoke	9,740	205,000	343,000
Tar	4,360	4,000	8,000
Neuse	5,550	5,000	10,000
Cape Fear	9,030	40,000	20,000
Peedee (Yadkin)	10,600	222,000	334,000
Santee	14,800	400,000	590,000
Savannah	11,100	290,000	438,000
Ogeechee	5,140	4,300	10,700
Altamaha	14,100	57,600	94,000
Apalachicola	18,800	204,000	326,000
Tombigbee	42,000	50,000	100,000
Alabama		275,000	487,000
Sabine	20,700	2,020	5,050
Trinity	17,700	3,180	12,800
Brazos	48,800	7,460	20,900
Colorado	39,000	28,100	55,700
Guadalupe	10,500	36,000	43,400
Rio Grande	248,000	267,000	545,000
Pecos	.....	55,000	87,800

RESOURCES OF POWER IN SOUTHERN STREAMS—*Continued*

Rivers.	Drainage Area, Square Miles.	Estimated Minimum.	Horsepower Maximum.
Ohio	204,000	40,000	100,000
Tennessee	.....	1,210,000	1,950,000
Cumberland	.....	76,800	159,000
Green	.....	11,400	28,500
Kentucky	.....	18,100	45,100
Licking	.....	5,360	13,400
Big Sandy	.....	21,700	57,600
Kanawha	.....	402,000	1,020,000
Monongahela	.....	71,000	283,000
Osage	.....	7,890	19,000
Arkansas	177,500	110,000	182,000
Cimarron	.....	11,500	44,000
Canadian	.....	83,900	348,000
Red	.....	48,900	148,000
Minor Streams	312,520	267,600	449,300
	1,253,740	4,918,910	9,210,350

The principal hydro-electric power companies operating in the South are the Alabama Power Co., the Georgia Railway & Power Co., the Southern Power Co., and the Tennessee Power Co.

These systems with the exception of the Alabama Power Co., are inter-connected and form an unbroken transmission line 1000 miles long, from Nashville, Tenn., to Henderson, N. C. The table below gives information about some of the more important individual companies:

POWER DEVELOPMENTS OF THE SOUTH

Company and Station.	Developed Water Power Kw.	Auxiliary Stream Plants Kw.h	Developed Total Kw. h.	Yearly Load Factor.	Mile H. T. Line.
Georgia Ry. & Power Co.					
Tullah Falls, Ga.	72,000				
Mathis					
Bull Slince	10,500				
Dunlap	2,200				
Butter St. P. H	.....	11,000			
Davis St. P. H	.....	10,500	106,200	.....	617
Alabama Power Co.					
Lock 12 Coosa R.	67,500				
Jackson Shoals	2,000				
Warrior	.....	50,000			
Gadsden	.....	10,000	129,500	50.5%	1000

POWER DEVELOPMENTS OF THE SOUTH—*Continued*

Company and Station.	Developed Water Power Kw.	Auxiliary Stream Plants Kw.h	Developed Total Kw. h.	Yearly Load Factor.	Mile H. T. Line.
Columbus Power Co.					
City Mills	1,500				
North Highlands	6,900				
Goat Rock	20,000				
Columbus, Ga	.....	9,000	37,400	45%	130
Carolina Power & Light Co.					
Buckhorn Falls (Cape Fear)	2,500				
Neuse River	400				
Raleigh P. H	.....	3,750			
Goldsboro P. H	.....	700			
Henderson P. H	.....	225	7,575	.....	188
Southern Power Co.					
Bridgewater	35,000 Kva				
Lookout Shoals	22,800 Kva				
Fort Mill	6,600 Kva				
Fishing Creek	37,500 Kva				
Great Falls	30,000 Kva				
Rocky Creek	30,000 Kva				
Watree	70,000 Kva				
Ninety-nine Islands	22,500 Kva				
Greenville P. H	.....	8,000			
Mt. Holly P. H	.....	8,000			
GreensboroP H	.....	8,000			
University P. H	.....	12,500	280,900	.....	2000
Tennessee Power Co.					
Ocoee R. No. 1	18,750				
Ocoee R. No. 2	15,000				
Great Falls	9,750				
Hales Bar	42,000				
Parkville, Tenn	.....	13,000			
Chattanooga	.....	3,500			
Nashville	.....	12,500			
Knoxville	.....	6,250	120,750	.....	600
Yadkin River Power Co.					
Blewett Falls (Yadkin)	32,000	.....	32,000	.....	184
Total	547,400	166,925	714,325	.....	4719

It will be noted that in almost all cases the water power is supplemented by steam power. Under conditions which existed before the present high-price era, power plants located in or near the coal fields of the South could, if properly equipped and managed, furnish power at a figure not entirely out of competition with water power. In certain favorable localities steam power could be produced for about three mills a horse-power hour including depreciation and interest on the investment, which is equivalent to about $30 per full horse-power year. At Kingsport, Tenn., there is a large steam power plant which furnishes power for such local industries as a cement plant, pulp mill, wood extract plant, dye works, chlorine plant, wood alcohol plant, etc. I believe the present rate there is about 7 mills per kw.h. or about $45 per full horse-power year.

In view of the high cost of developing water power and the fact that most chemical industries had rather purchase this than go to the expense of developing such themselves, it would seem that for those who are moderate users of power, there would be great possibilities in the utilization of some of the cheap fuels of the South by locating plants in the coal or natural gas fields. The first cost of even the most economical steam or gas plant will be far below that of developing the average water power.

I have said nothing of the power development at Muscle Shoals as the present status of this project seems uncertain. The proposed project would have produced about 680,000 H.P. of which only about 280,000 H.P. was to be employed in industries already located there. If this development is completed as contemplated about 400,000 H.P. should be available for new enterprises.

Labor.

Southern labor, and particularly negro labor, has had many disparaging remarks made about it and is popularly supposed to be shiftless. I have done considerable construction work in the South, as well as in the North, and I do not find that a day's work done by southern labor is materially less than that done by the foreign labor so generally throughout the North. My experience with operation has been largely with plants of the character of cement mills, lime kilns, and works of a similar character. It is, of course, difficult in the South to get the skilled labor necessary to operate these plants, but this is also true of plants located away

from the center of these industries. Such labor must generally be brought in from outside and the difficulty in the case of the South has been to get this labor to stay and work alongside the negro.

The negro can be trained to perform many of the simpler tasks of the chemical factory. He will work at a semi-skilled job for much less increase of pay over a laborer's job than will a white man. Many negroes are essentially what we call "corn field darkies"; such are usually shiftless and cannot be depended upon to work regularly. They are accustomed to the spurts required in farming such as the planting season, the cotton picking season, etc., alternated with periods of idleness.

Very good white labor can be obtained in the mountains of the South and much native white labor is employed in the Appalachian district.

There is one thing which can be said for the negro, and also for the southern native white laborer, he is not Bolshevish in his tendencies. Labor unions find it difficult to absorb him and he strikes only on great provocation and after much urging.

In Baltimore, negroes are employed quite generally in chemical and metallurgical plants at the same rate of wage as the foreigners and there seems to be little prejudice against them.

Certain general facts about labor conditions in the South are of interest to the manufacturer. The cost of living is less in the South than in the North due to the proximity of the food supply and the need of fewer clothes, and less adequate housing. The latter item is of importance to those manufacturers who must establish their own colony of workmen. A much more cheaply constructed house will serve in the mild southern climate than is necessary in the colder north. This advantage is increased by cheaper building materials and particularly cheaper lumber than is found in most eastern manufacturing cities.

There is a general belief that the southern climate in the summer is particularly enervating. This may be true to some extent of the coastal and gulf plain, but much of the mineral wealth is in the highlands, where the nights are cool and the humidity is low, making conditions here not much different from the other parts of the country.

I am giving below the wages for some of the more important classes of workers in the various cities of the south:

WAGE SCALE OF SOUTHERN CITIES AND NEW YORK, NOV., 1919

	Bricklayers.	Carpenters.	Hod Carriers.	Struc. Iron Workers.	Common Labor.
Baltimore	$1.00	$0.80	$0.50	$0.87½	$0.40
Atlanta	0.90	0.70	0.45	0.72½	0.35
Knoxville	.....	.....	.....	.....	0.25
Birmingham	.....	.....	.....	.....	0.35
New Orleans	0.87½	0.78	0.60	0.75	0.35
Savannah	.....	.....	.....	.....	0.30
Chattanooga	.....	.....	.....	.....	0.27½
Memphis	1.00	0.75	0.62½	.....	0.30
New York	0.87½	0.81¾	0.57½	0.87½	0.50

Taxes.

In an address recently made by a prominent business man at a dinner given in his honor, he stated that one of the reasons which had induced his company to build its new factory in Baltimore rather than in the New England city in which it had formerly been located, was the fact that the saving in taxes alone in the southern city would in twenty years amount to enough to build the new factory.

This brings to the attention the fact that the State and city taxes generally in the South are much less than in the east and New England. The rate of taxation does not materially differ in the three sections but there is a very marked difference in the assessment on the property. While the northern cities and States usually assess on amounts ranging from 75 to 100% of the actual value of the property, the southern States and cities usually assess on much less than this—generally not more than 50% of the value and in South Carolina only 25%. This saving is worth considering in determining on a plant location as it lowers the fixed charges by just so much. The tax rate of 1918 within the corporate limits of most of the southern cities was about 1.5% of the actual value of the property including State, county and city taxes, of which about one-third is State and county tax.

Basic Raw Materials.

In considering the South as a locus for chemical plants, it is not only advisable to consider the resources as to specific ores, etc.,

but also as to sulphuric acid, lime and soda-ash and the raw materials from which these are produced—sulphur and pyrite, limestone and salt.

It is not my intention to give more than passing attention to the sulphuric acid resources of the South, as the occurrence of pyrite and sulphur in this section is well known and they will also be fully described in another paper which will be read at the meeting. In the Ducktown, Tenn., region there are two large plants making sulphuric acid from smelter fumes which would otherwise be lost. These can unquestionably produce this chemical at a very low cost. At Baltimore is located another very large sulphuric acid plant—that of the Davison Chemical Co. This plant is one of the most modern in existence. Its facilities for handling ore are of the best and it can turn out a large tonnage of acid at a low cost.

The Louisiana sulphur deposits are well known and have been extensively described in technical literature. Virginia has long been the most important domestic producer of pyrites. Under normal conditions the value of the output of its mines reaches nearly a million dollars. Some pyrite is also mined in Georgia and there are numerous undeveloped deposits of this mineral in both the Carolinas. The proximity of some of the seaboard cities to Cuba makes the Cuban pyrite available for manufacturing purposes in this section.

The sulphuric acid resources of the South have been developed principally with a view to the manufacture of acid phosphate. Very little of the output of its various factories is utilized otherwise and practically all acid makers are either manufacturers of fertilizers or of acid phosphate.

Lime.

The lime resources of the South are extensive. While the quantity burned there is not unusually large, good undeveloped deposits are numerous and widely distributed. All along the slopes of the Appalachian mountains are to be found deposits of pure limestone, while further west we have extending from Louisville to south of Birmingham, the limestone of the Mississippi Valley. Yet farther west, in Missouri, a broad limestone area covers the greater part of this state, the northern part of Arkansas and the northeast corner of Oklahoma.

The limestone deposits in Virginia and Maryland are, for the

most part, high calcium but there are included in the area numerous beds of dolomite. As you go farther south, however, the dolomitic beds become less prominent. In Missouri and Arkansas the magnesian stone predominates although there is some high calcium stone.

The limestone area of the South coincides pretty generally with the mineral belt and is, in most cases, adjacent to the coal fields, in fact in Alabama and Kentucky the two areas practically coincide. The limestone area contains also numerous water power sites. This is particularly true of the Alabama section.

In addition to the limestone deposits there are extensive deposits of shells along the gulf coast of Texas and Louisiana. These are very pure and can be burned in a rotary kiln to excellent lime. Cement is already manufactured from these shells in Texas.

Those chemical manufacturers who prefer to purchase their lime will find no difficulty in getting a steady supply of high calcium or magnesian lime at a low figure. The Valley of Virginia is dotted with lime plants and there are also numerous lime plants near Martinsurg, W. Va., and Frederick, Md. These now supply an extensive trade in chemical lime which goes to all parts of the east and middle west. Farther south we have plants scattered pretty generally throughout the territory, all the states except Louisiana and South Carolina producing some lime.

There are approximately six hundred lime kilns in the South and about fifteen first-class hydrating plants. "The Mineral Resources for 1917" gives the number of hydrated lime plants in this territory as 32, but fully half of these are make-shift affairs and probably an even greater proportion of the kilns are of the obsolete pot type.

In spite of the number of the kilns in operation, there is room in this section for further development of the lime industry, particularly in the way of remodeling some of the older existing plants.

The South has 14 cement plants, one or more in each State except Florida, North and South Carolina, Louisiana, Mississippi, Arkansas and Indian Territory. One southern plant has a capacity of 5000 bbls. per day and several have capacities in excess of 3000 bbls.

The South also presents some attractive locations for cement plants at points where there is a good local market. This is particularly true in certain sections where fuel and limestone are found adjacent to each other; notably in central Kentucky and

Alabama. In the latter section cheap hydro-electro power is also available. In northwestern Louisiana these exist limestone, clay and natural gas in close proximity and no cement plant in this State or in Mississippi, Indian Territory or northern Texas. The possibility of developing the gulf shell deposits for both lime and cement, using oil or gas for a fuel, should be mentioned also.

The per capita consumption of cement in the South in now much less than in other parts of the country. Her roads are poor and her farmers use concrete very little. With the general increased prosperity of the rural South, there will be a great era of road building in the next few decades and the concrete road is now acknowledged to be the best. This will make the existing cement plants inadequate to supply the demand. In fact this condition now exists and cement is being shipped into the Carolinas from the Lehigh districts of Pennsylvania.

The production from salt brines and from dolomite of calcined magnesia to be used in the making of magnesia coverings for steam pipes, etc., for pharmaceutical use and for oxychloride cement has never been undertaken in the South. The raw material dolomite exists here and also a market for the product.

Salt.

Texas and West Virginia have long been known as prominent producers of salt. Five of the southern states produce salt on a commercial scale. In addition to the two mentioned are Louisiana, Virginia and Oklahoma. So far, however, only one plant in the South in manufacturing soda ash, namely the plant of the Mathieson Alkali Works, at Saltville, Va. There are no soda-ash plants located in either West Virginia or Louisiana and it would seem that there were excellent opportunities in both states for the manufacture of soda ash and other chemicals produced from salt and brine.

In Louisiana, salt occurs in two districts, namely in the valleys of the Red and Sabine Rivers in the northern part of the state, and, in the southern part of the state, near the gulf coast on what is known as the Five Islands. Rock salt is mined on two of these —Weeks Island and Averys Island. Salt mined in Louisiana is much purer than that obtained anywhere else in the world, containing 99.6 to 99.8% of sodium chloride. The supply is prac-

tically unlimited and present mining operations are controlled solely by the demand. Limestone and natural gas are both near these deposits.

The center of the salt industry in Virginia is at Saltville, Smythe County, and the area extends for about 20 miles northeast of the village of Plasterco along the Holston River. Salt is now pumped from about 25 wells and is made into soda ash, etc.

The West Virginia salt area is confined to a small territory in Mason County on the Ohio River and Malden a few miles from Charleston on the Kanawha River. The West Virginia brines are most interesting to chemists because they contain large quantities of bromine and calcium and magnesium chlorides. Both calcium chloride and bromine are already produced here. The opportunities for the manufacture of soda-ash, etc., for the recovery of bromine and its salts, magnesium salts and calcium chloride would seem to be particularly good here. Cheap coal is available in this section and there is also a large water power development at Kanawha Falls. There would seem, therefore, to be some opportunity for electrochemical developments in connection with this deposit.

Bauxite.

The South has long been recognized as the source of bauxite, the ore of aluminum. Arkansas now produces about 90% of the bauxite of the country, while the balance comes from Tennessee and Alabama. Practically all of this ore has been sent north for working into the metal until recently when the Aluminum Company of America began developments in North Carolina.

It is hardly worth while to call attention to the opportunities in this section for the manufacture of aluminum. The location of the reduction plant of the Aluminum Company of America at Marysville, Tenn., and also the building of a plant by a French concern at Whitney, N. C., (which has since been taken over by the former company also) has drawn attention to this section.

There seems to be no effort to make alum in the South. While it is generally conceded that alum is made in order to dispose of sulphuric acid, it is also a fact that there is a great deal of cheap sulphuric acid in the South. There are small deposits of bauxite which can be very easily mined in sections where acid can be obtained very readily. Bauxite from such deposits is now

shipped to Philadelphia, Boston and other eastern cities to be converted into alum. Incidentally the alum is brought back to the South and sold in various cities for water purification, etc. It would seem, therefore, as if there was an excellent opportunity for the manufacture of aluminium salts in the South.

The production of bauxite bricks is also an industry which might be developed to advantage in the South, particularly as very little fire-brick is manufactured in this section. The bauxite in Georgia is particularly adapted to the manufacture of such brick. In many sections of this field there exists a bauxite earth which is admirably adapted to the manufacture of alumina brick.

The development of water power would also allow the manufacture of "alundum" and other fused alumina abrasives.

Barytes and Paint Ores.

Prior to the war a large quantity of barytes came from Europe. The principal source of supply now, however, is from the three southern states of Missouri, Tennessee and Georgia. It is barely possible that the Austrian ore will again enter the country and that the plants along the Atlantic Seaboard will be supplied from this source.

Prior to the war the barytes industry of this country was confined almost entirely to the manufacture of ground barytes and of lithopone. The quantity of barium salts manufactured was only a very small part of that consumed. Since the war, however, the barium industry has received a great impetus and practically all the salts of barium including the peroxide are now manufactured in quantity in this country.

There are a number of plants in the South which grind and bleach barytes and there are three plants which make barium chemicals, chiefly sulphate and carbonate. So far no lithopone has been made south of Baltimore.

The advantages of the South as a locus for lithopone plants would seem evident because of the fact that the necessary zinc can also be found in locations adjacent to the barytes. This is particularly true of southwest Virginia, eastern Tennessee and Missouri. I believe that the zinc manufactured in Virginia is purer than that found anywhere else in the country and the purity of the zinc influences to some extent the economy of the process and the quality of the lithopone.

Lithopone is now made in the South by the Chemical Pigments Corp., of St. Helena, Md., and the Mineral Refining and Chemical Co., of St. Louis, and barium salts by four firms—and Durex Chemical Co., Sweetwater, Tenn.; the Rollin Chemical Co., Charleston, W. Va.; the Clinchfield Products Co., Johnson City, Tenn., and the Virginia Consolidated Chemical Corp., Bristol, Va.

In addition to barytes many other materials for the manufacture of paint are to be found in the South in large quantity, such as yellow and red ochers, white clay, sienna, iron carbonate, graphite, zinc, lead and chrome ores, etc. Add to these turpentine, acetic acid, menhaden oil and we have assembled all of the raw material needed by the paint manufacturer which are of domestic origin.

Clay, Feldspar and Pottery Minerals.

Some of the most important clay deposits of the country are located in the South. Clays will be found here suitable for pottery, brick and terra cotta, for sizing paper and weighting cloth.

The Georgia secondary clays or kaolins are well known and there are extensive producers of washed clay in the neighborhood of Macon, Ga. This clay goes almost exclusively into the paper trade. For this purpose it is only necessary to remove the silica sand from the clay. These kaolins contain considerable titanium oxide which is not removed by simple washing and which gives color to the clay when burned. By treatment with sodium carbonate the clay slip is made more fluid and the titanium also may be settled out. With clay purified in this manner fine white tile and hotel china can be made.

Some of the Georgia clays contain a small percentage of iron. Chemical research should be applied to the bleaching of this clay and making it available for pottery and other purposes.

Feldspar and pure silica sand are other minerals used in the manufacture of pottery. These are mined in various localities in North Carolina, Virginia and Maryland. There is a large grinding plant at Erwin, Tenn., which grinds North Carolina spar and sends it to the potteries of the North. We are designing now a plant of a similar nature which will grind spar and silica and which is to be built at Kingsport, Tenn. This town is near the North Carolina feldspar deposits and a very pure silica sand is also found at Kermit, Va., 18 miles away. There are clays near Kingsport and

I have seen some beautiful china made from this combination. Kingsport would, therefore, seem to be an excellent site for a pottery as low sulphur coal is also cheap there.

Another location for a pottery is in the Macon and Augusta section of Georgia. Feldspar can be found in the neighborhood and it adjoins the white clay belt of this state.

Excellent glass sand is found in many sections of the South and much sand from Hancock, Md., and Berkeley, W. Va., is shipped to the Pittsburgh glass factories. It is also proposed to open the deposit at Kermit, Va., for shipment to the Ohio and middle west glass factories.

Electro-chemical Possibilities.

I have touched on the hydro-electric power resources of the South and of the adjacent limestone and coke. This opens up the field for the production of carbide and cynamid. The limestone will also be needed as a flux in electro furnace operation.

Iron ores are found so generally throughout the south Appalachian region that there would be no difficulty in obtaining these near at hand for making ferro-alloys.

The phosphates of Tennessee are near the water powers and hence are available for the production of phosphorus, phosphoric acid and ferro-phosphorus. The Louisiana sulphur could be employed to advantage in the manufacture of carbon-bisulphide.

There are also numerous deposits of manganese in Virginia suitable for ferro-manganese and permanganate. There is some chrome ore in North Carolina but the deposit has not been explored to any extent. The Maryland high-grade chrome deposits are said to be worked out, but I have recently heard that operation was to be resumed using a lower grade ore and concentrating this.

Virginia is so far the only producer of rutile, the ore of ferro-titanium. Other deposits exist in North Carolina and near Magnet Cove, Ariz. So far no ferro-titanium is made in the South.

There is to be found in the south Appalachian region a great deal of very pure quartz. The section would, therefore, seem to offer advantages for the manufacture of ferro-silicon, as well as for fused quartz ware and silicon carbide (carborundum).

Miscellaneous Chemicals.

Arsenic was extensively produced during the war at Brinton, Floyd Co., Va. I believe, however, that this plant has now ceased to operate and that plants making arsenic direct from the ores cannot succeed when brought into normal competition with the by-product arsenic from the western smelters.

The recovery of fluorides from the gases from the acidifying dens in the manufacture of acid phosphate is now practiced at a number of southern chemical works. These compounds find extensive use in enameling and for concrete floor hardening, etc. The quantity now going to waste from the fertilizer industry is ample to supply any demand and as the latter increases more companies will no doubt recover the fluorides.

The graphite now mined in Alabama is crushed and concentrated there, after which it is shipped to other parts of the country for final working up. There would seem to be openings in the South for the utilization of this graphite for the making of crucibles and automobile lubricants.

The potash resources of the South are confined entirely to feldspar and the cerisite schists or potash shales of Georgia. The latter would seem the more desirable material as it is more easily quarried than feldspar and contains fully as much potash as will the average lot of the latter mineral. Furthermore the potash seems to be much more easily liberated from sericite than from feldspar by either heat or chemical reagents. The utilization of these shales as a source of potash is a promising line of chemical research. The recovery of potash from cement kilns is practiced by two southern cement companies—the Security Cement & Lime Co., Hagerstown, Md., and the Clinchfield Portland Cement Co., Kingsport, Tenn.

Gypsum exists in three southern states—Virginia, Oklahoma and Texas. Seven companies with nine mills now produce plaster of Paris in the South and there are two plants in Virginia, two in Texas and five in Oklahoma. The industry in these three fields would seem to be fully developed but there are some deposits in Louisiana which would bear looking into and if the deposits justify it, development with a view to supplying the territory east of this. There is also the possibility that there may develop at any time a large quantity of by-product calcium sulphate from the production

of phosphoric acid. The production of good plaster from this material is very difficult but its probable cheapness would justify research to this end.

The largest production of fuller's earth, used now so generally for the purification of animal, vegetable and mineral oils, comes from Florida. There are some excellent deposits in Texas both in point of quality and quantity. The Texas earth is particularly desirable for the bleaching of cottonseed oil.

I am appending to this paper a table showing the location of mineral deposits in the South. This will not only give an idea as to the extent of southern mineral resources but will also enable the manufacturer to determine the proximity of the minerals which he employs to any given location.

Transportation and Markets.

I have not touched on two very important factors in the development of chemical industries in any locality, namely transportation and the market. Any good recent map of the South will show the railroad facilities at any point. The present status of the southern railroads is good. The more important of the carriers have spent considerable money in the last ten years on the development of their lines. The southern railroads are largely single track affairs but the traffic does not justify double tracking at this time. The road beds of most of the southern railways have now been much improved, curves have been straightened out, grades leveled, timber bridges replaced by steel and concrete ones, heavier rails laid, etc. The present rolling stock is, like that of most of the northern roads, inadequate to the needs of the traffic. This condition will no doubt be remedied as soon in one section as in the other. The southern railroads are all anxious to develop industries along their lines and manufacturers contemplating southern locations can count on their co-operation.

As to markets, some thirty million people live in the South and their wants are pretty much those of the seventy million who live elsewhere. Any plant which is to supply the wants of the ultimate consumer, such for example as the manufacture of paint, china ware, pharmaceutical preparations, etc., will find a market in the South for its product. The chemical industry is a very intricate one and often the product of one plant finds it way as a raw mate-

rial into another and finally after going through a second and possibly even a third process, emerges as an article desired by the general public. For this reason it may not be practicable to start certain plants in the south in spite of excellent manufacturing inducements because the other industry which employs its output may not be established there. For such plants, however, the markets of the central west are often open and in some instances notably where southern ores are now sent north it would manifestly often save freight to ship the product rather than the raw material, such for example as sending blanc fixé rather than barytes to the paint manufacturer.

Finally, I do not wish anyone to misunderstand me as saying that there is a location for all of the plants to which I have called attention. In some instances there may be no market now but one may develop in a few years. The law of supply and demand works in the South just as it does elsewhere. The manufacturer who knows his business can readily determine whether there is an opening for his particular industry in the South and when. I am very far from advocating the indiscriminate establishment of chemical plants in the South, or for that matter elsewhere by inexperienced parties simply because local conditions seem to suggest them. I feel sure that the prosperity of the South demands that its industries shall be in the hands of competent technologists and efficient business men and that she is content to wait until such see her opportunities. It is to this end that I have presented this lengthy brief in her behalf rather than with any desire to furnish the promoter with ammunition for his guns.

MINERAL LOCATIONS OF THE SOUTH.

(Fuels, Limestone and Iron, Lead, Zinc and Copper Ores not included.)

M = Mined in Appreciable Quantities.
A = Abandoned or Non-producing mines.
O = Occurs in apparently Commercial Quantities but not mined.

Arsenopyrite:

Canton Mine, Cherokee Co., Ga.
Charles Mine, Forsythe Co., Ga.
King's Mountain Mine, Cleveland Co., N. C.
Brinton, Floyd Co., Va.
Pilot Mountain, Montgomery Co., Va.

Asbestos:

M Hollywood, Habersham Co., Ga.
M Sall Mountain, White Co., Ga.
O In Baltimore and Hartford Counties, Md. (poor grade)
O In Jackson, Polk and Mitchell Counties, N. C.
A Mattox, Amelia Co., Va.
A Rocky Mount, Franklyn Co., Va.
A Body Camp, Bedford Co., Va.

Asphalt: (Bituminous sandstone, shale and limestone chiefly.)

A Leighton and Russellville, Colbert Co., Ala.
Russellville, Franklin Co., Ala.
M Jackfork Valley (10 miles west of Tuskahoma), Pushmataba Co., Okla.
M Ada, Pontotoc Co., Okla.
M Bee Spring, Edmondson Co., Ky.
M Tar Hill, Grayson Co., Ky.
M Young's Ferry, Warren Co., Ky.
O Numerous localities in oil belt in Kentucky, West Virginia, Texas and Oklahoma.

Barite:

M Pratt's Ferry, Calhoun Co., Ala.
M Leeds, Jefferson Co., Ala.
M Cartersville, Bartow Co., Ga.
M Elton, Murray Co., Ga.
M Shyrock Ferry, Woodford Co., Ky.
M Ambrose, Jessamine Co., Ky.
O Fredonia, Caldwell Co., Ky.
O Harrodsburg, Mercer Co., Ky.
O Danville, Boyle Co., Ky.
O Millersburg, Bourbon Co., Ky.
O Lexington, Franklyn Co., Ky.
M Eugene, Henley and Hickory Hill, Cole Co., Mo.
M Tiff, Cadet, Mineral Point and Potosi, Washington Co., Mo.
M Blackwell, St. Francois Co., Mo.
M Etterville and Bagwell, Miller Co., Mo.
O In Franklin, Jefferson and Morgan Counties, Mo.
M Stackhouse, Madison Co., N. C.
M Bessemer City, Gaston Co., N. C.
A Hillsboro, Orange Co., N. C.
M King's Creek, Cherokee Co., S. C.
M Sweetwater, Tenn. (in Monroe, Loudon and McMinn Counties).
A Del Rio, Coke Co., Tenn.
A Trousdale, Smith Co., Tenn.
O In Sievier, Jefferson and Washington Counties, Tenn.
M Otter River, Camphill Co., Va.
M Toshes, Motleys and Hurt, Pittsylvania Co., Va.

M Honaker, Russel Co., Va.
A Thaxton, Bedford Co., Va.
A Marion, Smythe Co., Va.
A Richlands, Tazewell Co., Va.
A Mechanicsville, Louisa Co., Va.

Bauxite:
M Rock Run, Cherokee Co., Ala.
O In DeKalb and Calhoun Counties, Ala.
M Little Rock, Ark.
M Adairsville, Bartow Co., Ga.
M Cave Spring, Floyd Co., Ga.
M McIntire, Gordon, Toomsboro and Ironton, Wilkinson Co., Ga.
M Andersonville, Sumter Co., Ga.
O Oglethorpe, Macon Co., Ga.
O Warm Springs, Meriwether Co., Ga.
M Elizabethton, Carter Co., Ga.
M Sherman Heights, Hamilton Co., Tenn.

Bromine: (In salt brine.)
M Malden, Kanawha Co., W. Va.
M Hartford and Mason, Mason Co., W. Va.

Chromite:
O Hog Creek, Towne Co., Ga.
O In Herd and Fayette Counties, Ga.
A Bare Hills and Soldier's Delight, Baltimore, Md.
A Rock Springs, Cecil Co., Md.
O In Montgomery, Harford and Carroll Counties, Md.
O Democrat and Stocksville, Buncombe Co., N. C.
O Webster, Jackson Co., N. C.
A Mine Hill, Yancey Co., N. C.
A Dranesville, Fairfax Co., Va.

Clay, Common Pottery: (Not white. See also White Clay.)
M Mineral Springs, Barbour Co., Ala.
M McLeans, Elmore Co., Ala.
O Edgewood, Autauga Co., Ala.
M Yalaha, Richmond and Oklahumpka, Lake Co., Fla.
O Edgar, Johnson and McMeekin, Putnam Co., Fla.
M Groveton, Columbia Co., Ga.
M Oakwood and Gillsville, Hall Co., Ga.
M Williams Mill, Crawford Co., Ga.
M Bogert, Oconee Co., Ga.
O In Chattanooga, Clarke, Glascock, Washington and White Counties, Ga.
M Hickman, Fulton Co., Ky.
M Columbus, Hickman Co., Ky.

O Scale, Palma and Hardin, Marshall Co., Ky.
O Waco and Bybeetown, Madison Co., Ky.
O Bonieville, Hart Co., Ky.
M Risefield, La Salle, Parish, La.
M In Baltimore, Cecil, Alleghany, Frederick and Washington Counties, Md.
M Stoutsville, Monroe Co., Mo.
M Versailles, Morgan Co., Mo.
M St. Charles, St. Charles Co., Mo.
M Harrisonville, Cass Co., Mo.
M Regina, Jefferson Co., Mo.
M Gainville, Ozark Co., Mo.
O In Copper, Franklin, Henry, Jasper, Johnson, Linn, Livingston, Marion, Scott, Stoddard, Texas, Vernon Counties, Mo.
M Luthers, Buncombe Co., N. C.
O In Burke, Gaston, Lincoln, Randolph, Chatham, Johnston, Moore, Union and Wilkes Counties, N. C.
M Granileville and elsewhere, Aiken Co., S. C.
O In Kershaw, Lexington and Richland Counties, S. C.
M Hico and Hollow Rock, Carroll Co., Tenn.
O La Grange, Fayette Co., Tenn.
O Grand Junction, Hardeman Co., Tenn.
O Henry and Peryear, Henry Co., Tenn.
O Summit, James Co., Tenn.
O Pinson, Madison Co., Tenn.
O Graysville, Rhea Co., Tenn.
O In Hanover, Henrico and King William Counties, Va.
M Bridgeport, Harrison Co., W. Va.
M Ravenswood, Jackson Co., W. Va.
M Morgantown, Monongalia Co., W. Va.
M Parkersburg, Wood Co., W. Va.
O Elkins, Randolph Co., W. Va.

Clay, White (for Pottery, Paper, etc.), Kaolin, etc.:
M Valley Head and elsewhere, DeKalb Co., Ala.
O Rock Run, Cherokee Co., Ala.
O Pegram, Colbert Co., Ala.
O Gadsden, Etowah Co., Ala.
O Kymulga, Talladega Co., Ala.
O Gibson, Glascock Co., Ga.
O Cuthbert, Randolph Co., Ga.
O Hephzibah, Richmond Co., Ga.
M Butler, Taylor Co., Ga.
M Dry Branch, Twiggs Co., Ga.
M Lewiston, Gordon and McIntyre, Wilkinson Co., Ga.
M Laketown, Ballard Co., Ky.
O Clay Switch, Graves Co., Ky.
O Lena, Rapids Parish, La.

O Spring Ridge, Caddo Parish, La.
M Bollenger and Glen Allen, Bollenger Co., Mo.
M Versailles, Morgan Co., Mo.
M Warren, Warren Co., Mo.
O Jackson, Cape Girardeau Co., Mo.
M Webster, Jackson Co., N. C.
O Franklin, Macon Co., N. C.
O Penland, Mitchell Co., N. C.
O Almond and Bryson City, Swain Co., N. C.
O Tahlequah, Cherokee Co., Okla.
M Aiken and Bath, Aiken Co., S. C.
M Columbia, Richland Co., S. C.
M Tennessee Kaolin Mines, Stewart Co., Tenn.
O Sparta, Henry Co., Tenn.
O Leakey, Edwards Co., Texas.
O Oak Level, Henry Co., Va.
M Kaolin, Cold Spring, Pkin and elsewhere Augusta Co., Va.
O In Amelia, Amherst, Nelson, Nottoway, Cumberland, Prince Edward, Fauquier, Henrico, Smyth and Wythe Counties, Va., also.

Feldspar:
M Hissop, Coosa Co., Ala.
O Bradley, Jones Co., Ga.
O Eatonton, Putnam Co., Ga.
O Forsythe, Monroe Co., Ga.
M Woodstock, Granite and Hollofield, Baltimore Co., Md.
M Laurel, Montgomery Co., Md.
M Cononwingo, Cecil Co., Md.
M Spruce Pine, Mitchell Co., N. C.
A Bells, Bedford Co., Va.
A Prospect, Prince Edward Co., Va.
M Jonca, Ste. Genevieve Co., Mo.
M O'Quinn, Fayette Co., Texas.

Fluorspar:
M Crane, Marion and Mexico, Crittenden Co., Ky.
M Salem, Livingston Co., Ky.
A Spring Station, Woodford Co., Ky.
O Princeton, Caldwell Co., Ky.
O Morton's Mill, Fayette Co., Ky.
O Ambrose, Jessamine Co., Ky.
O Cumberland, Alleghany Co., Md.
A Carthage, Smith Co., Tenn.
O Watauga Point, Carter Co., Tenn.
O In Truesdale and Wilson Counties, Tenn.
O Shepherdstown, Jefferson Co., W. Va.

Fuller's Earth:

M Klondike and Fair Play, Saline Co., Ark.
M Midway, Jaimison and Quincy, Gadsden Co., Fla.
M Ellenton, Manatee Co., Fla.
O Gainesville, Alachua Co., Fla.
O High Falls, Columbia Co., Fla.
O Rock Bluff, Liberty Co., Fla.
M Pikes Peak, Twiggs Co., Ga.
M Dry Branch, Twiggs Co., Ga.
M Attapulgus, Decatur Co., Ga.
O Groveton, Columbia Co., Ga.
O Burleson, Fayette, Smith, Washington and Cherokee Counties, Ga.
M Sommerville, Burleson Co., Texas.

Glass-Sand:

O Gate City and Trussville, Jefferson Co., Ala.
O Guion, Izard Co., Ark.
M Ruddells, Ark.
M Tarpon Springs, Hillsboro Co., Fla.
M Lumber City, Telfair Co., Ga.
M Beeky Creek, Calloway Co., Ky.
M Olive Hill and Lawton, Carter Co., Ky.
M Tip Top, Hardin Co., Ky.
M Ludlow, Kenton Co., Ky.
M Opelousas, La.
A Robinson, Anne Arundel Co., Md.
M Hancock, Washington Co., Md.
M Horn Island and elsewhere, Tishomingo Co., Miss.
M Hickory and Roff, Okla.
M Klondike, Grays Summit and Pacific, Franklin Co., Mo.
M Crystal City, Jefferson Co., Mo.
M Jackson, Cape Girardeau Co., Mo.
M Black and Ulmers, Barnwell Co., S. C.
M Pee Dee, Clarendon Co., S. C.
M La Grange, Fayette Co., Tenn.
O Coal Creek, Anderson Co., Tenn.
O Chilhowee, Blount Co., Tenn.
O Saulsbury, Hardeman Co., Tenn.
O Knoxville, Knox Co., Tenn.
M Catawba Mountain, Roanoke Co., Va.
M Mendota, Va.
O Kermit, Scott Co., Va.
O Stapleton Mills, Amherst Co., Va.
O Greenville, Augusta Co., Va.
O Balcony Falls, Rockbridge Co., Va.
M Sturgisson, Monongalia Co., W. Va.
M Berkeley Springs, Morgan Co., W. Va.
M Green Spring, Hampshire Co., W. Va.

M Corinth, Holmes and Independence, Preston Co., W. Va.
M Silica, Randolph Co., W. Va.
M Grafton, Taylor Co., W. Va.
M Craddock, Upshur Co., W. Va.

Grahamite:
M Moullin Mine and Impsom Valley, Atoka Co., Okla.
O Jackfork Valley (10 miles W. Tuskahoma), Pushmataha Co., Okla.
O Loco, Stephens Co., Okla.
M Parkersburg (25 miles southeast), Ritchie Co., W. Va.

Graphite:
M Ashland, Clay Co., Ala.
M Mountain Creek, Chilton Co., Ala.
A Christiana, Randolph Co., Ala.
O Rockford and Goodwater, Coosa Co., Ala.
O Bluehill, Tallapoosa Co., Ala.
M Barritt's Mountain, Alexander Co., N. C.
A King's Mountain Mine, Cleveland Co., N. C.
O Waynesville, Haywood Co., N. C.
O Graphiteville, McDowell Co., N. C.
O Method, Wake Co., N. C.
O Lone Grove, Illano Co., Tex.
O Buck Mountain, Albemarle Co., Va.
O Front Royal, Warren Co., Va.

Gypsum:
A Tokie, Pike Co., Ark.
O Panasoffkee, Sumter Co., Fla.
O Rayburn's Salt Wks., Bienville Parish, La.
O Lake Charles, Calcasieu Parish, La.
O Grand View, Caldwell Parish, La.
O Pine Prairie, St. Landry Parish, La.
A Cato, Rankin Co., Miss.
M Homestead and Watonga, Blaine Co., Okla.
M Cement, Caddo Co., Okla.
M Okarche, Canadian Co., Okla.
M Rush Springs, Grady Co., Okla.
M Eldorado, Jackson Co., Okla.
M Peckham, Kay Co., Okla.
M Quinlan, Woodword Co., Okla.
O In Harmon, Stephens and Washita Counties, Okla., also.
M Acme and Quanah, Hardeman Co., Tex.
M Hamlin, Jones Co., Tex.
O Kiowa Peak, Stonewall Co., Tex.
M Saltville, N. Holston and Chatham Hill, Smyth Co., Va.
M Plasterco, Washington Co., Va.

Halloysite:

M Sulphur Springs, DeKalb Co., Ala.
O Stevenson, Jackson Co., Ala.
O Calera, Shelby Co., Ala.
O Gore, Chattanooga Co., Ga.
M Rising Fawn, Dade Co., Ga.
O In Floyd, Fulton, Catoosa, Cherokee and Walker Counties, Ga.

Infusorial Earth (Kieselguhr, Tripoli, Diatamaceous Earth, Infusorial Earth, etc.):

M Eustis, Lake Co., Fla.
M Lyons Creek, Anne Arundel Co., Md.
O In Miocene formation in Anne Arundel, Charles, Calvert Counties, Md.
M Dalton, Chariton Co., Mo.
M Racine and Seneca, Newton Co., Mo.
O Hillsboro, Jefferson Co., Mo.
O In Ottawa Co., Okla.
M Salters Depot, Williamsburg Co., S. C.
M Wilmot, King George Co., Va.
O Greenland Wharf, Layton, Carters Wharf and other points along the Rapahannock River in King George and Essex counties, Va.
O Richmond, Henrico Co., Va.

Manganese, Pyrolusite (Manganiferous Iron Ore not included):

A Cushman, Independence Co., Ark.
A Little Rock, Pulaski Co., Ark.
M Cartersville, Emerson and Rowland Spring, Bartow Co., Ga.
M Can Spring, Floyd Co., Ga.
A Brookville, Montgomery Co., Md.
A In Washington Co. (near Harpers Ferry), Md.
O Point of Rocks, Frederick Co., Md.
A Lehigh and Hunton, Coal Co., Okla.
O McCormick, Abbeville Co., S. C.
O Breezewood, Greenwood Co., S. C.
A Elizabethtown, Carter Co., Tenn.
O Del Rio, Cocke Co., Tenn.
M Stapleton, Amherst Co., Va.
M Crimora Station, Augusta Co., Va.
A Troutville, Botetourt Co., Va.
M Evington, Mt. Athos and Otter River, Campbell Co., Va.
A Midway Mills and Warminster, Nelson Co., Va.
A Staneyton, Page Co., Va.
M Powells Fort, Shenandoah Co., Va.
A Sugar Grove, Smyth Co., Va.
M Happy Creek, Warren Co., Va.
A Wytheville, Wythe Co., Va.

Mercury:

M Terlinqua, Sandy Butte and McKinney Springs, Brewster Co., Tex.
O Presidio Co., Tex., also.

Mica (Muscovite):

M Bowden, Clay Co., Ala.
M Wedowee, Randolph Co., Ala.
O Micaville, Cleburne Co., Ala.
O Magnet Cove, Hot Springs Co., Ark.
A Elberton, Elbert Co., Ga.
A Gainesville, Hall Co., Ala.
M Tworun, Lumpkin Co., Ala.
M Blairsville, Dalonega and elsewhere, Union Co., Ala.
A Scaggsville and Woodstock, Howard Co., Md.
A Laurel, Montgomery Co., Md.
M At various points in Ashe, Buncombe, Burke, Cleveland, Gaston, Haywood, Jackson, Lincoln, Macon, Mitchell, Rutherford, Stokes, Watauga and Yancey Counties, N. C.
A Anderson, Anderson Co., S. C.
M Reedy, Greenville Co., S. C.
O Dahlberg, El Paso Co., Tex.
M Amelia and Jetersville, Amelia Co., Va.
A New London, Bedford Co., Va.
A Goochland, Goochland Co., Va.
A Hewlett, Hanover Co., Va.
A Ridgeway, Henry Co., Va.
A Chatham, Pittsylvania Co., Va.

Molybdenite:

Haile Mine, Lancaster Co., S. C.

Monazite and Other Rare Earth Minerals:

M Bridgewater, Brindletown, Connellys Springs, etc., Burke Co., N. C.
M Belwood, Casar, Lawndate, Mooresboro, etc., Cleveland Co., N. C.
M Cherryville, Gaston Co., N. C.
M Statesville and Bethany Church, Iredell Co., N. C.
M Mars Hills and Democrat, Madison Co., N. C.
M Ellenboro, Oak Springs, Rutherford, etc., Rutherford Co., N. C.
O Zirconia, Henderson Co., N. C.
O Ray Mine, Yancey Co., N. C.
O Wiseman Mine, Spruce Pine and other points, Mitchell Co., N. C.
O Amelia C. H., Amelia Co., Va.
O Marietta, Greenville Co., S. C.
O Barringer Hill, Llano Co., Tex.
M Gaffney, Cherokee Co., S. C.
O In Anderson, Laurens, Oconee, Pickens and Spartanburg Counties, S. C.

Ocher—Red and Brown:

M Attalla, Etowah Co., Ala.
A In Tishomingo Co., Miss.
O Amazonia, Andrew Co., Mo.
O Hickman Mills, Jackson Co., Mo.
M Riverton, Warren County, Va.

Ocher—Yellow:

M Noosada Station, Elmore Co., Ala.
O In Antauga, Fayette, Marion and Tuscaloosa Counties, Ala.
M Cartersville, Bartow Co., Ga.
M Laketon and Wyckliffe, Ballard Co., Ky.
M Marion, Crittenden Co., Ky.
M Paducah, McCracken Co., Ky.
O Highland Landing, Marshall Co., Ky.
M Catoctin, Frederick Co., Md.
O In Anne Arundel and Prince George Counties, Md.
A Iuka, Tishomingo Co., Miss.
O Knobnoster, Johnson Co., Mo.
O Calhoun, Henry Co., Mo.
O In Buchanan, Lafayette, Ray and Ozark Counties, Mo.
A Bedford City, Bedford Co., Va.
A Bermuda Hundred, Chesterfield Co., Va.
A Leesburg, Loudon Co., Va.
A Stanleyton and Marksville, Page Co., Va.
A Keezleton and elsewhere, Rockingham Co., Va.
O Harpers Ferry and Shepherdstown, Jefferson Co., Va.
O In Cabell, Hardy, Lewis, Pendleton and Wayne Counties, W. Va.

Phosphate Rock:

M Veto, Limestone Co., Ala.
M Batesville, Independence Co., Ark.
O St. Joe, Searcy Co., Ark.
M Clark, Newberry and elsewhere, Alachua Co., Fla.
M Floral City, Hernando and Istachatta, Citrus Co., Fla.
M Fort White, Columbia Co., Fla.
M Bay City, Hernando Co., Fla.
M Plant City, Hillsboro Co., Fla.
M Anthony and Dunellon, Marion Co., Fla.
M Bartow, Ft. Meade, Mulberry and elsewhere, Polk Co., Fla.
A Hull, De Soto Co., Fla.
A Buda, Orange Co., Fla.
M Midway, Woodford Co., Ky.
M Coosaw River Tributaries, Ashley and Edisto River Basin, S. C.
O Wando and Cooper River Basins, S. C.
M W. Nashville, Davidson Co., Tenn.
M Parsons, Decatur Co., Tenn.
M Wales, Giles Co., Tenn.

M Centerville, Togg and Swan Bluff, Hickman Co., Tenn.
M Big Swan, Lewis Co., Tenn.
M Mt. Pleasant and elsewhere, Maury Co., Tenn.
M Lick Creek, Perry Co., Tenn.
M Boma, Putman Co., Tenn.
M Gallatin and Rogana, Summer Co., Tenn.
M Brentwood and Franklin, Williamson Co., Tenn.

Pyrite:

A Pyriton, Clay Co., Ala.
O Dahlonega, Lumpkin Co., Ala.
O Elkmont, Limestone Co., Ala.
A Hot Springs, Garland Co., Ark.
M Villa Rica, Bremen and Reeds Mountain, Carroll Co., Ga.
M Creighton and Ball Ground, Cherokee Co., Ga.
A Acworth, Cobb Co., Ga.
A Westbrook, Haralson Co., Ga.
A Dahlonega, Lumpkin Co., Ga.
A Hiram, Paulding Co., Ga.
O In Barton, Dawson, Greene, McDuffie, Murray, Oglethorpe, White Counties, Ga.
O In Anne Arundel, Montgomery and Prince Georges Counties, Md.
M Rolla, Phelps Co., Mo.
M Kelso, Scott Co., Mo...
M Morrellton and Leslie Mine, Franklin Co., Mo.
A Kings Mountain, Cleveland Co., N. C.
A Bessemer City, Gaston Co., N. C.
O Colossus, Union Co., N. C.
O Gold Hill, Rowan Co., N. C.
M Kershaw Co., S. C.
O In Chesterfield, Lancaster, Spartansburg, Union and York Counties, S. C.
M Stony Creek, Carter Co., Tenn.
O In Cheatham, Greene and Moore Counties, N. C.
M Mineral, Louisa Co., Va.
M Monarat, Carroll Co., Va.
M Austinville, Wythe Co., Va.
M Dumfries, Prince William Co., Va.
O In Botetourt, Buckingham, Culpeper, Dinwiddie, Fauquier, Goochland, Montgomery, Floyd, Orange, Rockbridge, Spotsylvania and Stafford Counties, Va.

Quartz and Silica:

M Trussville, Jefferson Co., Ala.
M Crystal Springs, Montgomery Co., Ark.
A Glen Morris and Woodstock, Baltimore Co., Md.
M Flintville and Deer Creek, Harford Co., Md
M Louisville, Carroll Co., Md.

A Montgomery Co., Md.
A Mariotsville, Howard Co., Md.
A Ranger, Cherokee Co., N. C.
M Mt. Holly, Gaston Co., N. C.
M Kings Creek, Cherokee Co., S. C.
M Iron City, Tenn.
M In Lawrence and Wayne Counties, Tenn.

Rutile, Ilmenite, Nelsonite, etc.:
O Magnet Cove, Hot Springs Co., Ark.
O Shooting Creek, Clay Co., N. C.
O In Macon, Alexander and Iredell Counties, N. C.
O Lenoir, Caldwell Co., N. C.
O Barringer Hill, Llano Co., Tex.
O Fly Gap, Mason Co., Tex.
M Roseland and Arrington, Nelson Co., Va.
M Peers, Goochland Co., Va.
M Gouldin, Hanover Co., Va.

Samarskite and other Yttrium:
O Wiseman and other mica mines, Mitchell Co., N. C.
O Brindleton, Burke Co., N. C.
O Barringer Hill, Llano Co., Tex.

Sienna:
O Oxford, Cherokee Co., Ala.

Strontianite (and Celestite):
O Burnet, Burnet Co., Tex.
O Austin (near), Travis Co., Tex.
O Cedar Cliff, Mineral Co., W. Va.

Tetradymite:
O Silver Hill, Davidson Co., N. C.
O Asbury Mine, Montgomery Co., N. C.
O In Burke, Cabarrus, Gasto and McDowell Counties, N. C.

Umber:
Troutdale, Grayson Co., Va.
Luray, Page Co., Va.

Uranite, Uranophate and other uranium minerals:
O Penland and Spruce Pine, Mitchell Co., N. C.

Wavelite:
O Coal City, St. Clair Co., Ala.

Wolframite:

O Irish Creek, Rockbridge Co., Va.

Zircon and Zirconia ores:

M Zirconia, Henderson Co., Va.
O Sterling, Iredell Co., N. C.
O In Burke, McDowell and Rutherford Counties, N. C.
O Amelia, Amelia Co., Va.
O Ashland, Hanover Co., Va.

SOME DEVELOPED MINERAL RESOURCES AND CHEMICAL INDUSTRIES OF THE SOUTHERN STATES

By ANDREW M. FAIRLIE

Read at the Savannah Meeting, Dec. 5, 1920

The mineral resources and chemical industries of the southern states to be considered in this paper are:

1. Phosphate rock, whose resultant industries are:

   (*a*) The mining of phosphate rock;
   (*b*) The manufacture of ground phosphate rock;
   (*c*) The manufacture of acid phosphate;
   (*d*) The manufacture of complete fertilizer.

2. Sulphur.
3. Pyrites.
4. Pyrrhotite, and cupriferous sulphides; the dependent industries of these last three classes being:

   (*a*) The mining of the minerals;
   (*b*) The manufacture of sulphuric acid;
   (*c*) The smelting of copper ores.

Phosphate rock has been grouped with three apparently unrelated minerals obviously because of the interdependence of the respective manufactured products—acid phosphate and sulphuric acid.

The object in preparing this paper is to present in compact form before the Institute, at this meeting, held in a City of the South, some of the salient facts, already well known probably, to those familiar with the subjects, pertaining to these rather prominent industries of the southern states. A realization of what has been done in these fields of endeavor may serve as some indication of what may yet be accomplished in other fields, still undeveloped.

The term "phosphate rock" includes the calcium phosphates, of which apatite has probably the most definite and constant compo-

sition. Two varieties of apatite are recognized, namely, fluorapatite, $Ca_5(PO_4)_3F$, and chlorapatite, $Ca_5(PO_4)_3Cl$. Other phosphatic minerals are manganapatite, hydroapatite, "phosphorite," staffelite, and pseudoapatite.

A concise statement of the origin of phosphate rock, together with a description of the methods of mining (both underground and open pit), and an outline of washing and drying methods for the elimination of impurities and the preparation of the rock for the market, will be found in an article entitled "Phosphate," by E. H. Sellards,* obtainable from the State Geologist, Tallahassee, Florida.†

The United States, with a production in 1913 (the latest wholly pre-war year) of 3,111,221 long tons of phosphate rock, or practically one-half of the production of the entire world, leads all other countries as a producer of that mineral. All of this country's production, with the exception of 5,053 tons, was produced in the southern states;‡ and Florida, with an output of 2,545,276 long tons, and Tennessee, with 451,559 long tons, together produced over 96 per cent of the entire output of the country. The only other phosphate-producing states worthy of mention are South Carolina and Kentucky, and the production in the latter State, as late as 1917, amounted to only a few thousand tons. The deposits of South Carolina were the first to be mined in America.§ Phosphate rock has been mined in past years in Arkansas, but the production in this State has apparently stopped. Phosphatic minerals or marls are known to exist in four other southern states, namely, Virginia, North Carolina, Alabama and Georgia, and brief descriptions of these various deposits will be found in the paper by Sellards,|| referred to previously.

On account of the preponderating influence on the market of the production from the States of Florida and Tennessee, the following extracts from Sellards' paper, with reference to the deposits of these two States, may be of interest.

* E. H. Sellards: Mineral Industries and Resources of Florida. Reprinted from the Sixth Annual Report of the Florida State Geological Survey, p. 71 ff.

† Acknowledgement of indebtedness to Dr. Sellards' paper is here made, for much of the data regarding the phosphate minerals, and the distribution of phosphate rock, etc., repeated here.

‡ W. C. Phalen: The Production of Phosphate Rock in 1913. Mineral Resources of the United States, Pt. II, 1914. P. 273.

§ According to Sellards, actual mining began in 1867.

|| *Op. cit.* p. 86, ff.

Phosphate Deposits of Florida

"The phosphate produced in Florida includes two kinds, namely, hard rock and land pebble phosphates.

"The matrix in which the hard rock phosphate is imbedded is extremely variable. The formation includes a mixture of materials from various sources and of the most diverse character, further complicated by pronounced chemical activity within the formation itself. The prevailing phase of the formation is feebly coherent, more or less phosphatic, light gray sand. Aside from these sands the principal materials of the formation are clays, phosphate rock, flint boulders, limestone inclusions, pebble conglomerate, erratic and occasional waterworn flint pebbles, vertebrate and invertebrate fossils, and occasional pieces of silicified tree trunks.

"Phosphate rock, although the constituent of special economic interest, nevertheless makes up a relatively small part of the formation. The phosphate in these deposits occurs as fragmentary rock, boulder rock, plate rock, or pebble. The boulders are often of large size, in some instances weighing several tons, and must be broken up by blasting before being removed from the pit. It is also necessary to operate a rock crusher in connection with all hard rock phosphate mines to reduce the larger pieces of rock to a size suitable for shipping. The relative amount of material that it is necessary to handle to obtain a definite amount of phosphate is always variable with each pit and with the different parts of any one pit. The workable deposits of phosphate lying within this formation occur very irregularly. While at one locality the phosphate may lie at the surface, elsewhere it may be so deeply buried as not to be economically worked; while a deposit once located may cover more or less continuously a tract of land some acres in extent, elsewhere a deposit, appearing equally promising on the surface, may in reality be found to be of very limited extent. As to location, depth from surface, extent into the ground, lateral extent, quantity and quality, the hard rock phosphate deposits conform to no rule. The desired information is to be obtained only by extensive and expensive prospecting and sampling.

"The materials above the phosphate deposits include pale yellow incoherent sand and in some localities clayey sand. The incoherent sands are variable, an average thickness being from 5 to 15 feet, although as much as 30 feet have been observed.

"The land pebble phosphates of southern Florida are much more

uniform in their manner of occurrence than are the hard rock deposits. The phosphate is in the form of pebble rock imbedded in a matrix of clay, sand and soft phosphate. Although variable from place to

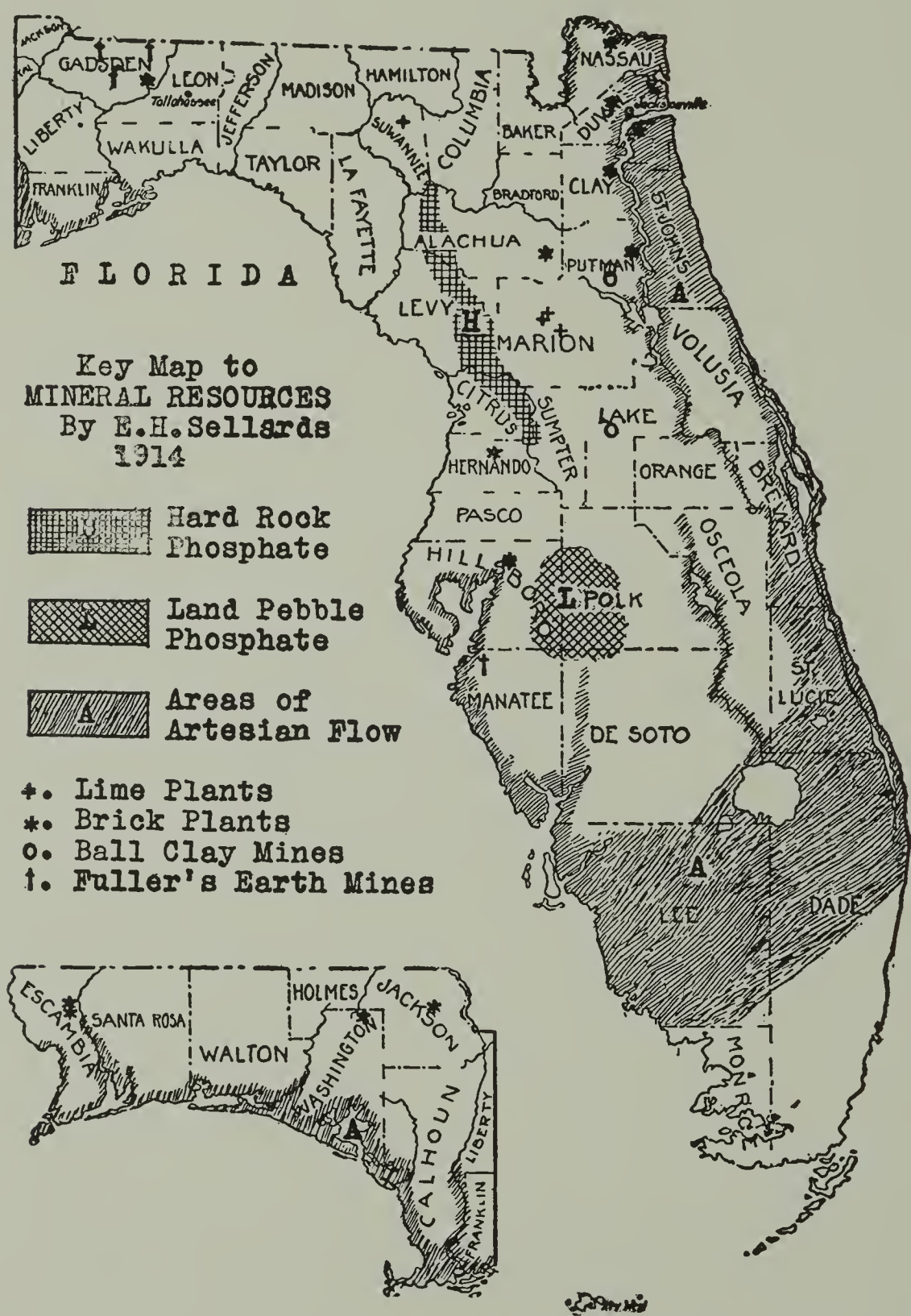


FIG. 1.—Deposits of Phosphate Rock in Florida.

place the phosphate bed has an average thickness of from 8 to 10 feet, its maximum thickness being from 18 to 20 feet. The overburden, which consists largely of sand and sandy clays, with local

indurated or calcareous ledges, has an average thickness of from 10 to 14 feet.

"The best grade of land pebble rock, when properly washed, dried and selected, permits a guarantee of 75 or 76 per cent tricalcium phosphate. Other grades on the market range from 62 to 75 per cent. The hard rock phosphates range from 79 to 83 per cent, although selected samples run as high as 84 or 85 per cent tricalcium phosphate.

"Practically all of the hard rock phosphate mined in Florida is exported. Of the land pebble phosphate produced, over 40 per cent was exported in 1913."

The location of the deposits of phosphate rock in Florida is shown on the map (Fig. 1) reproduced herewith.*

Phosphate Deposits of Tennessee

"In Tennessee several more or less distinct types of phosphate occur, only two of which, however, blue rock and brown rock, are being mined at present. The blue phosphate occurs as a bedded deposit within, but forming the lowest member of, the Chattanooga formation of Devonian age, and resting directly upon Ordovician limestone. The blue phosphates are said to vary in grade from about 30 to 85 per cent of tricalcium phosphate. Iron and aluminum in the better grade of rock aggregate less than three per cent. The beds vary in thickness from zero to 50 inches, although the bed furnishing high grade rock rarely exceeds 20 inches in thickness.

"The brown rock of Tennessee is at the present time (1914) of greater commercial importance than the blue rock. This rock occurs in irregular deposits lying near the surface and resting on limestone. The overburden consists usually of residual material including clay, some phosphate, and a limited amount of sand. Its thickness is extremely variable, although averaging 8 or 10 feet. The phosphate consists of a shelly rock, breaking up into pieces of varying size, and of small variegated pebbles which in mass have a dark brown color. Locally the small pebble rock predominates, forming a scarcely coherent mass having a brownish color. A phase of the material, known locally as "muck" deposit, consists of a mass of small pebbles, often not exceeding a pin head in size."

The phosphate deposits of Tennessee are in the central part of the State. According to J. S. Hook, the centers of production lie in

* From Sellards, *op. cit.*

Maury, Hickman, Lewis, and Giles Counties. The most important deposits are those in the vicinity of Mount Pleasant, in Maury County, eleven miles southwest of Columbia, the county seat. Further information regarding the phosphate rock deposits of Tennessee can be found in the April (1914) issue of *The Resources of Tennessee.**

Extensive deposits of phosphate rock are known to exist in Utah, Idaho and other western states, but as late as 1917 the West produced only 0.6 per cent. of the entire output of the country for that year. That the output for 1917 (15,096 tons) represented an increase of 786 per cent. over the production for 1916, indicated, however, a tendency towards increased activity in that section.

The following table† illustrates in eloquent manner the marked effect of the European war on the phosphate industry of this country:

PHOSPHATE ROCK MARKETED IN AND EXPORTED FROM THE UNITED STATES, 1913–1917

Year.	Proportion of Exports to Domestic Production (Per Cent).	Marketed Production (Long Tons).	Exports (Long Tons).
1913	44	3,111,221	1,366,508
1914	35	2,734,043	964,114
1915	14	1,835,667	253,421
1916	12	1,982,385	243,678
1917	6	2,584,287	166,003

The rapid decline in the exports of phosphate rock from this country is shown graphically on the accompanying diagram (Fig. 2).

Naturally, as Florida is the largest producer of phosphate rock, the brunt of the stagnation of the export business was borne by that State. The following summary‡ of the shipments of phosphate rock from Florida from 1913 to 1918, inclusive, is interesting, in comparison with the preceding table:

* J. S. Hook: The Brown and Blue Phosphate Deposits of South-Central Tennessee. The Resources of Tennessee. State Geological Survey. Vol. IV. No. 2, p. 51, ff.

† American Fertilizer Hand Book, 1919; p. C-6.

‡ Compiled from the American Fertilizer Hand Book, 1919, and "Statistics on Mineral Production in Florida during 1918" by Herman Gunter, State Geologist. Press Bulletin No. 11, Oct. 6, 1919, p. 5.

SUMMARY OF SHIPMENTS OF PHOSPHATE ROCK IN FLORIDA, 1913-1918 INCLUSIVE

Year	Pebble Rock.			Hard Rock.			Pebble and Hard Rock Combined.		
	Exported long tons.	Domestic long tons.	Total long tons.	Exported long tons.	Domestic long tons.	Total long tons.	Exported long tons.	Domestic long tons.	Total long tons.
1913	887,398	1,168,084	2,055,482	476,898	12,896	489,794	1,364,296	1,180,980	2,545,276
1914	625,821	1,203,381	1,829202	303,172	6,517	309,689	928,993	1,209,898	2,138,891
1915	185,846	1,122,635	1,308,481	43,314	6,816	50,130	229,160	1,129,451	1,358,611
1916	172,427	1,296,331	1,468,758	28,045	19,042	47,087	200,472	1,315,373	1,515,845
1917	138,010	1,865,081	2,003,991	12,403	6,205	18,608*	150,413	1,872,186	2,022,599
1918	64,559	1,932,288	1,996,847	57,771	12,612	70,383*	122,330	1,932,288	2,067,230

* Includes soft rock phosphate.

It is apparent, from statistics furnished by the United States Department of Commerce, that during the first half of 1919 the export business in phosphate rock showed some signs of improvement.

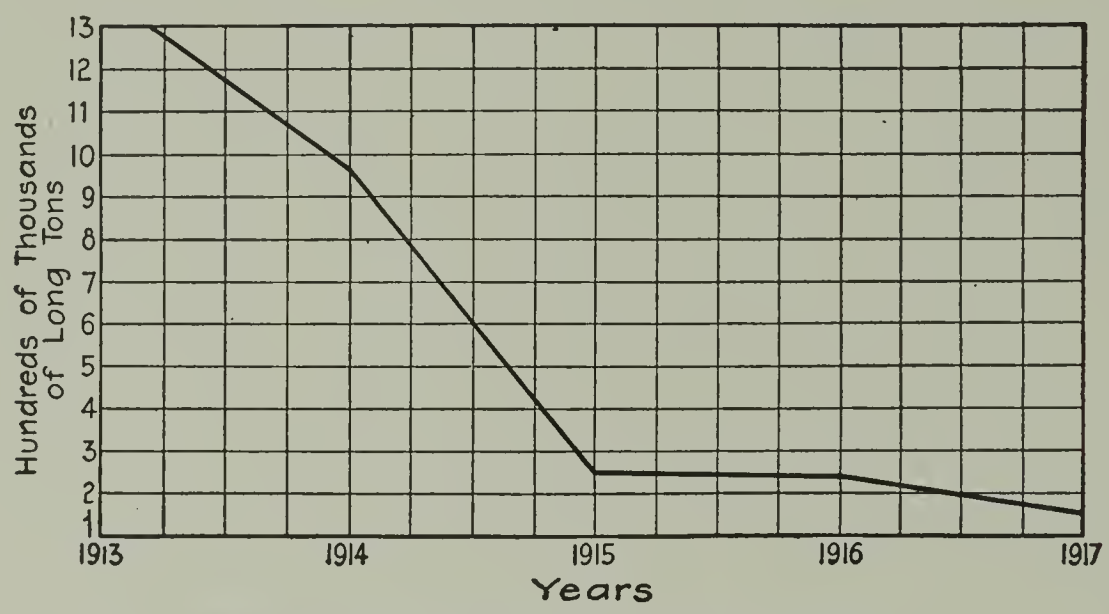


Fig. 2.—Exportation of Phosphate Rock.

For the fiscal year ending June 30, 1919, exportations of phosphate rock were as follows:

PHOSPHATE ROCK EXPORTED FROM THE UNITED STATES, YEAR ENDING JUNE 30, 1919

Kind of Rock.	Tons.	Value.
Land Pebble	78,027	$448,855
High Grade Hard Rock	80,834	715,104
All other	30,227	328,575
Total	189,088	$1,492,534

It will be noted that all of the foregoing statistics refer to shipments. The shipment tonnages are never the same as the tonnages of rock mined, for there are variable amounts in storage at the end of each year. The tonnage of rock mined in 1918 shows a decrease of 443,247 long tons under that mined in 1917, the diminished output being a reflection of conditions due to our entry into the war, such as difficulty in securing labor, restrictions placed on fuel distribution and shipping facilities, etc.

The total value of the shipments in 1917 was $5,464,493, and in 1918, $6,090,106. The total production of phosphate rock in Florida

since the beginning of mining it in 1888 to the close of 1918 is estimated to be 35,210,314 tons, with a total valuation of over $129,000,000.*

The principal uses of phosphate rock are, for export as such, for the manufacture of "ground phosphate rock," and for the manufacture of acid phosphate. Smaller quantities of the rock are used in other industries, such as the manufacture of matches, and the manufacture of various chemicals—phosphoric acid, ammonium and sodium phosphates, etc.

Within recent years the use of ground phosphate rock as a fertilizer has been strongly advocated, and its use has been recommended in some quarters as a substitute for acid phosphate. The producers of phosphate rock have a direct interest in promoting the demand for the raw product, which they can afford to sell for a much lower price than acid phosphate can be sold for. On the other hand, the manufacturers of acid phosphate, and of sulphuric acid, are directly concerned with increasing the demand for acidulated rock. Much argument has therefore arisen, pro and con, regarding the real value of ground phosphate rock as a fertilizer. As a factor tending towards a decision of the subject in dispute, by a disinterested authority, the following extract from Bulletin No. 76,† issued by the Georgia Department of Agriculture, is to the point:

"Ground phosphate rock gives very small returns in soils deficient in organic matter, hence the poor results obtained when used on clay soils. It does much better in sandy soils containing much organic matter. Soil acids and rotting organic matter are regarded as making the phosphoric acid of the rock slowly available for plants.

"The ground rock can be mixed with compost or in the manure pile, or even sowed in the furrow with six or eight times its weight of manure, and then it will give some returns. Even on cotton lands that have very little organic matter present in their soils, the use of phosphate rock is better than the entire omission of all fertilizers. But for this crop, acid phosphate will net much richer returns even if bought at much greater prices.

"It is not to be concluded from the foregoing statements that ground raw phosphate is without any value. It most assuredly is of value on certain types of soil. But the farmer should be cautioned

* Statistics on Mineral Production in Florida during 1918, by Herman Gunter State Geologist. Press Bulletin No. 11, Oct. 6, 1919, p. 5.

† Bulletin No. 76, Georgia Department of Agriculture, 1918, p. 40, ff.

against indiscriminate buying at extravagant prices because of the extravagant claims of agents and dealers in this material."

Acid Phosphate

The first acid phosphate to be made by the modern method of treating phosphate rock with sulphuric acid was made in England in 1841.* The manufacture of acid phosphate is a simple chemical process. Approximately equal parts (the precise proportions being determined by the composition of the rock and the strength of the acid) of ground phosphate rock and 52-53 degree sulphuric acid are mixed in a cast-iron pan equipped with agitators or stirrers, and the mass is then dumped into bins or "dens." The equipment of an acidulating plant consists chiefly of rock mills, screens, mixers, acid tanks, and dens. On account of the scarcity of labor the tendency among manufacturers is to adopt modern labor-saving devices, such as traveling cranes and belts, overhead trolleys or tracks, Link-Belt or Jeffrey loaders, Thew shovels, grab buckets, etc., whereby large quantities of bulk materials may be handled quickly and cheaply.

The phosphate rock is ground so that 90–98 per cent. will pass through a 60-mesh screen, a weighed quantity of the "dust" is delivered, together with an accurately weighed or measured quantity of sulphuric acid of known strength, into a mixing pan of one or two tons capacity, a usual size being seven feet in diameter and two feet deep. The mass is stirred by mechanical stirrers until the initial stage of the reaction is completed (requiring from one to three minutes) and is then dropped into dens, where it is allowed to remain for at least twelve hours. If, after a night in the den, the acid phosphate is found to be in a reasonably dry state, it is removed from the den and placed in a large pile, where it is left for 30 days or more to "condition," (during which time the excess of moisture escapes) after which the acid phosphate, or superphosphate, is ready for shipment, or to be used for the manufacture of complete fertilizer.

Acid phosphate will ordinarily show on analysis the following composition:

Water soluble phosphoric acid	14 per cent.
Reverted phosphoric acid	2 " "
Insoluble " "	1 " "

* Sellards, *op. cit.*, p. 87.

The exports of acid phosphate, for the fiscal year ended June 30, 1919, were 51,405 tons, valued at $1,548,678. In 1917, it is estimated that about 4,000,000 tons of acid phosphate were manufactured in the United States, and that in 1918, about 4,500,000 tons were manufactured, the value of the product for the latter year being estimated at $76,500,000. For the manufacture of this huge tonnage of acid phosphate, large quantities of sulphuric acid have been required. But the sulphuric acid industry is dependent on the mineral industry for its principal raw material, and the development of the pyrite and sulphur deposits of the south has resulted from the demand for sulphuric acid.

Sulphur

Up to the year 1918, two companies, the Union Sulphur Co., Sulphur, Calcasieu Parish, La., and the Freeport Sulphur Co., near Freeport, Brazoria County, Texas, produced more than 99 per cent. of the sulphur mined in the United States. A small amount of sulphur was produced in three western states—Nevada, Wyoming and Colorado—but it is noteworthy that without the product from the southern states named, the output of brimstone from the United States was practically *nil*. During 1918 a third large producer—the Texas Gulf Sulphur Co., whose plant is at the mouth of the Colorado River, at Matagorda, Texas—and again a southern one, entered the field.

The production of brimstone in the United States for the year 1918 was reported as 1,352,283 tons.* The estimated production for 1917 was given as 1,137,000 tons.* The tonnage for 1917 was said by the United States Geological Survey to have been nearly 50 per cent. greater than in 1916, while during that year the production of brimstone was several hundred per cent. greater than in any year before the war.†

The character of the sulphur deposits in the southern states has been described by Philip S. Smith.‡ As is well known, these deposits are mined by the ingenious process developed by Herman Frasch. The original Frasch patent of Oct. 20, 1891, having expired, and the later patents having recently been declared invalid,§ the process,

* American Fertilizer Hand Book, 1919, p. 34.

† Philip S. Smith, Sulphur, Pyrite and Sulphuric Acid in 1917. Mineral Resources of the United States. 1917. Part II, p. 19.

‡ *Ibid*, p. 22.

§ "Sulphur Mining Freed of Patent Monopoly" Chemical Age, July, 1919, p. 33.

heretofore considered to be an exclusive one, appears now to be open to general use.

Besides the manufacture of sulphuric acid, the principal use of sulphur is in the manufacture of paper. Smith* states that paper manufacturers report a consumption of one-eight of a ton of sulphur for each ton of sulphite pulp manufactured. According to census returns, the sulphite pulp industry in the United States consumed 136,456 short tons of sulphur in 1914.

Prior to the war, very little sulphur was used in this country for the manufacture of sulphuric acid. But owing to the combined effect of increased demand for acid for the manufacture of munitions, and diminished supply of ships for the transportation of pyrites from Spain, the quantity of sulphur used for the manufacture of sulphuric acid has very greatly increased. The producers of acid report that 463,364 long tons of domestic sulphur were used by them in 1917†. Obviously, most of this must have come from the south.

Pyrites

Pyrites, or pyrite, whose main use is for the manufacture of sulphuric acid, was prior to the war imported into the southern states in large quantities from Spain. The exigencies of the war stopped most of this importation, and it was expected that the production of domestic pyrite would be greatly stimulated.

Virginia takes first rank among the states as a producer of pyrite, both as to quantity and value of output. In 1916 this State produced 148,502 long tons, valued at nearly one million dollars. Virginia's production in 1917 was 170,382 long tons. According to the Virginia State Geological Survey, the pyrite producers at present are:

The American Agricultural Chemical Corporation, operating the Cabin Branch Mines, Prince William County.

Grasselli Chemical Co., operating the Arminius Mine, Louisa County.

Sulphur Mining & Railroad Co., operating a mine three miles north of Mineral, Louisa County.

The General Chemical Co., operating a mine at Monarat, Carroll County.

Two mines in Louisa County, one owned by the Armour Fertilizer Co. and the other by Boyd-Smith Mines, Inc., were reported not

* Philip S. Smith, *op. cit.*, p. 23.
† Philip S. Smith, *op. cit.* p. 23.

operating in 1919. The Ohio Sulphur Mining Co., operating near Proffit, Albemarle County, reported development work in progress, and the Western Pyrites Corporation, operating near Garrisonville, Stafford County reported that they expected to resume production about the first of December.

Among the southern states, Georgia ranks second as a producer of pyrite. Georgia contributed 23,242 long tons in 1917.

According to S. W. McCallie,* the mines operating in the State of Georgia in 1917 were the Chestatee mine, six miles northeast of Dahlonega, Lumpkin County; the Standard mine near Creighton, Cherokee County; the Little Bob and Shirley mines near Hiram, Paulding County; the Marietta mine near Marietta, Cobb County; the Sulphur Mining and Railroad Company mine in Douglas County, and the Waldrop mine near Draketown, Haralson County.

Besides Virginia and Georgia, the southern states producing in 1917 were Alabama, Kentucky and Tennessee.

The total production of domestic pyrite in 1917 was reported by the United States Geological Survey as 462,662 long tons, an increase of ten per cent. over the 1916 production. The expected increase in pyrites production for the year 1918 did not materialize. This failure is attributed to the difficulty in securing labor, to the wartime restrictions placed on the delivery of mining equipment and other supplies, etc. The production for 1918 was estimated at 453,637 long tons,† or about 10,000 tons less than in the preceding year, or a loss of about two per cent.

Pyrrhotite and Copper Sulphides

Pyrrhotite, while it is, like pyrite, an iron sulphide, is considered separately, as it is found associated with copper sulphides, and has been treated along with the copper sulphides, primarily for the recovery of copper. The method of producing the sulphur dioxide from the sulphur, applied to these ores, is different from the method applied to pyrite. Otherwise the process of making the acid is practically the same.

The pyrrhotite deposits used for the manufacture of sulphuric acid and found associated with the sulphides of copper are mined in the Ducktown district in the southeastern corner of Tennessee, just

* S. W. McCallie, Hand-Book Mineral Resources of Georgia. Revised edition 1918, Geological Survey of Georgia, p. 35.

† American Fertilizer Hand Book, 1919, p. 32.

north of the Georgia line and just west of North Carolina. These deposits have been worked for many years for their copper values, and since 1907 sulphuric acid has been made as a by-product from the escaping fumes of the copper blast furnaces. There are two companies operating in the district—the Ducktown Sulphur Copper and Iron Co., Limited, and the Tennessee Copper Co.—and the total tonnage of ore mined annually by the two companies is in the neighborhood of half a million tons. The developed ore reserves at the mines of these companies is sufficient to permit the continuance of operations at the above rate for a number of years.

The process of smelting is the usual one for copper-iron sulphides, and consists of two operations: 1, smelting the ore in blast furnaces (in either one stage or two stages) for copper matte, containing 30 to 40 per cent. Cu; 2, blowing the matte to blister copper in basic lined converters. The amount of copper marketed is about 13,000,000 to 14,000,000 pounds annually.

Sulphuric Acid

According to the United States Geological Survey, the numbers of sulphuric acid plants operating in the several southern states in 1916 were as follows:

Alabama	12
Arkansas	1
Florida	5
Georgia	30
Louisiana	3
Maryland	11
Mississippi	5
North Carolina	12
Oklahoma	1
So. Carolina	15
Tennessee	6
Texas	3
Virginia	9
Total, Southern States	113
United States, (1917)	221

As fifteen plants were undistributed, the above total for the southern states is probably slightly too low. The value of the acid

produced in Virginia, Maryland, and Georgia in 1917 was more than $5,000,000 for each state.

During 1917 and 1918 many new sulphuric acid plants were built in the southern states, some of them of unusual size. A chamber plant of 400 tons daily capacity had been barely completed at Little Rock, Ark., when the armistice was signed, and had not yet been put into operation. At Brunswick, Ga., a chamber plant for the manufacture of 800 tons per day of 60 deg. Bé. acid was 40 per cent. completed on Nov. 11, 1918, but work on the plant was stopped after the signing of the armistice. A large contact plant at Nashville, Tenn. was 75 per cent. completed on the day of the armistice. Construction work on this plant also has been stopped.

Even before these large plants were designed, however, the South already had the largest sulphuric acid plant in the world—larger than either the Little Rock or the Brunswick plant—in the six and one-half million cubic feet of chamber space owned and operated by the Tennessee Copper Co., at Copperhill, Tenn. The average daily capacity of this plant is 1,000 tons (60 deg. Bé.), but the output often falls short of this amount, owing to fluctuations in the supply of gas. It has produced, for ten consecutive days, a daily average of 960 tons of 60 deg. Bé. acid, and there have been single days when over 1100 tons of acid were reported.*

For a long time the plant operated on the waste fumes of the copper blast furnaces only. Up to this year, no practical means had been developed of utilizing the waste fumes of the copper converters, and the equivalent of fifty tons or more daily of sulphur had for a long time escaped. Recently it has been found possible to utilize the converter gas, in addition to the blast furnace gas, without any addition whatever to the size of the acid plant. The gases from both sources (furnaces and converters) are combined in one common flue, and by means of lead fans of unusual size are drawn into the capacious chambers, and are there condensed into acid. By this means practically all the sulphur volatilized, by furnaces and converters, is recovered as acid. The percentage of sulphur recovery for the months of October and November this year, was 90 per cent., based on total sulphur volatilized. Since a recovery of 95 per cent. of the sulphur, for a plant built exclusively for the purpose of making sulphuric acid, is considered good practice, it is apparent that the sulphur

* Since this was written, this plant has produced a daily average of 1,000 tons 60 deg. Bé. acid for an entire month (Feb., 1920).

loss at this huge by-product plant is approaching an irreducible minimum. The dense white fumes, formerly seen escaping from the tall chimney, the irritating gases, which in past years had swept the

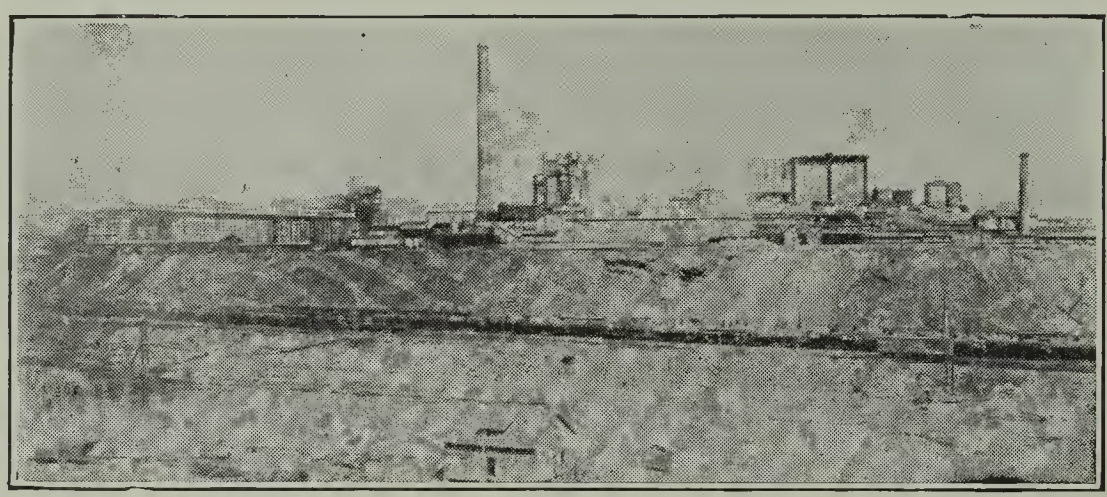


FIG. 3.—Gases Escaping at the Tennessee Copper Co. Plant.

furnace charging floors, a detriment to successful furnace operations, and a serious handicap to the furnace tenders, are to-day conspicuous by their absence. The atmosphere in the vicinity of the smelter is almost entirely free from sulphurous gas, and the 325 ft. chimney,

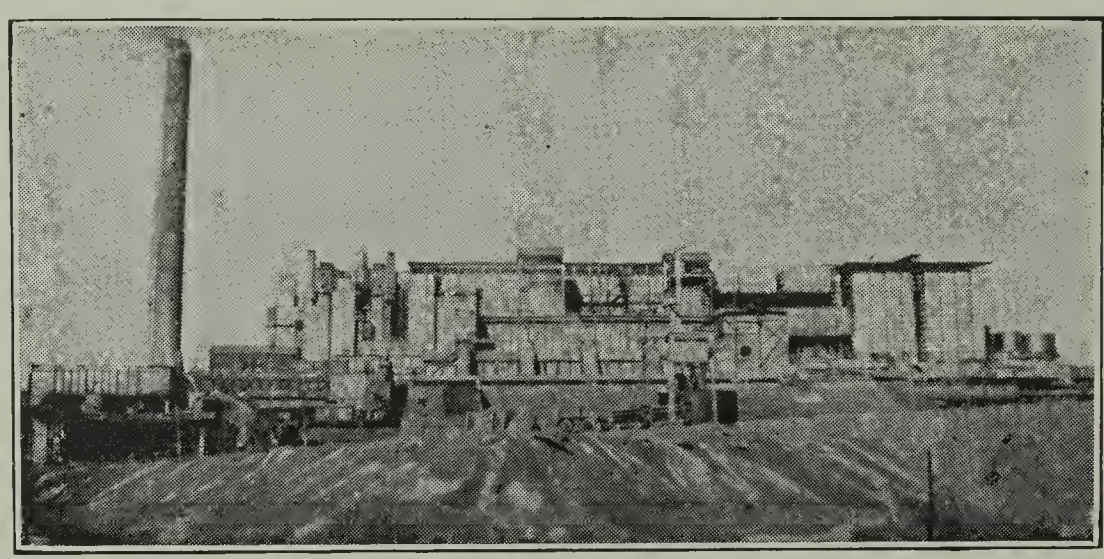


FIG. 4.—Fumeless Operation at the Tennessee Copper Co.

stands to-day, cold and empty, a monument to the waste of the past. The accompanying photographs (Fig. 3) illustrate the effects "before," and Fig. 4, shows the effect "after," instituting the recent improvements in operating methods.

Fertilizers

As the manufacture of acid phosphate is dependent on the sulphuric acid industry, so the vast fertilizer business of the United States is dependent on the acid phosphate industry. The three largest manufacturers of chemical manures are the American Agricultural Chemical Corporation, the Virginia-Carolina Chemical Co., and the International Agricultural Corporation. Most of the plants of these concerns are located in the southern states, and in addition there are scattered throughout the south many fertilizer plants owned and operated by the well-known meat packing concerns—Swift,

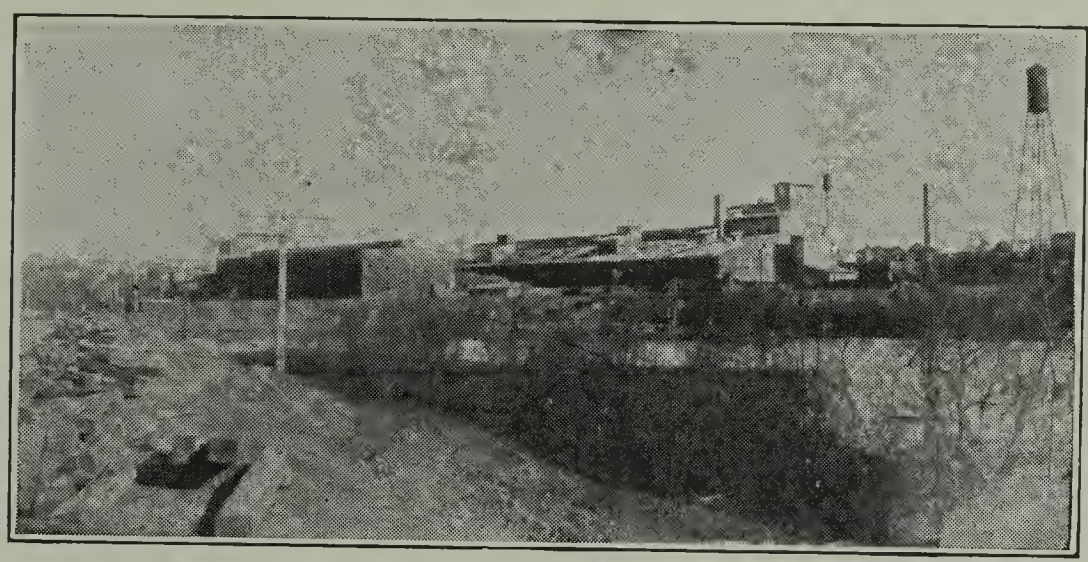


Fig. 5.—Armour Acid Phosphate Plant.

Morris and Armour—as well as many owned by independent concerns some large, such as the Royster Guano Co., and some smaller.

The manufacture of complete fertilizer consists in mixing acid phosphate in suitable proportions with nitrogenous materials, such as dried blood, tankage, fish scrap, or cottonseed meal, and potash salts. Sometimes the nitrogen or the potash is omitted, in which case the product becomes either "alkaline goods" (acid phosphate with potash) or "ammoniated superphosphate" (acid phosphate with nitrogenous material).

The complete fertilizer containing phosphoric acid, nitrogen, and potash, contains these ingredients in some definite proportion, such as 8 parts of the first to 2 parts of the second to 2 parts of the third—in which case the fertilizer would be known as "8-2-2" grade.

The manufacture and sale of fertilizers in the southern states is

regulated and controlled by state laws, supported by state chemists and their laboratories.

The following table shows the amount of fertilizers consumed in

Fig. 6.—Morris & Co. Fertilizer Plant.

the southern states in 1918, compared with the total consumption for the United States.

CONSUMPTION OF FERTILIZERS IN THE SOUTHERN STATES; AND IN THE ENTIRE UNITED STATES; FOR THE FISCAL YEAR ENDING IN 1918.*

States.	Tons Fertilizers consumed.
Alabama	289,990
Arkansas	88,500
Florida	197,954
Georgia	923,020
Kentucky	128,000
Louisiana	81,025
Maryland	173,000
Mississippi	104,700
North Carolina	921,962
Oklahoma	25,000
South Carolina	1,064,886
Tennessee	113,000
Texas	58,000
Virginia	430,549
Total, South	4,599,586
United States	6,991,743

* Compiled from American Fertilizer Hand Book, 1919, p. 20.

Fig. 5 is a photograph of the Armour Fertilizer Co., and Fig. 6

shows the fertilizer plant of Morris & Co., both of Atlanta. In each case, the sulphuric acid plant can be seen at the left.

The statistics given will serve to show the magnitude of these industries of the South. There are many other southern industries —mineral, chemical, and metallurgical—which will compare, as to capital involved and value of product, with the phosphate, sulphuric acid, and fertilizer industries, and some perhaps, will surpass these. The coal and iron of Alabama, the coal of Kentucky and Tennessee, the marble of Tennessee and Georgia, the oil of Oklahoma and Texas, the naval stores and cottonseed oil industries, the hardwood industries of the Appalachians—all these are southern resources, at least partially developed, the study of which will be profitable to those who are interested in the progress of the South.

504 Citizens & Southern Bank Building, Atlanta, Georgia.

DISCUSSION.

Dr. Thompson. A very interesting picture portrayed by Mr. Fairlie and now before us. Perhaps some one would like to pick out some salient feature and discuss it.

The Secretary. I would like to ask Mr. Fairlie with reference to the raw phosphate and acid phosphates, as to what proportion of the phosphate rock is used in the raw state. Is there any particular amount not treated with acid? Also, is there any possibility of a large use of the raw phosphates? You spoke of the fact of the soils containing organic matter being able to take the raw phosphate satisfactorily, so that it would be a question of what proportion of the South could use or might use the raw phosphate, and as to whether that is increasing or decreasing.

Mr. Fairlie. I have no definite figures as to the relative proportions of raw phosphate and acid phosphate used. In regard to the kind of soils in which the raw phosphate is valuable, these soils exist more in the North than they do in the South. The use of raw phosphates in soils is known as the "Illinois idea," and has been used with considerable success in Illinois. But no doubt there are other northern states where raw phosphates can be used to advantage. However, the southern soils are not so well adapted, and those versed in agriculture are advocating the use of acid phosphate in the South in preference to raw phosphates.

The Secretary. Isn't that raw phosphate ultimately absorbed

into the plant? If you use raw phosphate, wouldn't it in time all be dissolved?

Mr. FAIRLIE. It would disintegrate in time, but the advantage of the acid phosphate is that its effect is more immediate. If you wanted to wait 12 or 14 years you would get the benefit of the raw phosphate.

The SECRETARY. Your children would get the benefit of it?

Dr. THOMPSON. Isn't it generally understood, Mr. Fairlie, that if you examine the soils of any places where plants can grow, you usually find more of the mineral constituents than you could possibly add by means of fertilizers, but they are not available? And what the fertilizers do is to furnish immediately available materials?

Mr. FAIRLIE. There is not any doubt that there are in all soils chemicals which are not available as plant food, and the advantage of using fertilizers is to get chemicals into the soil in soluble form, available for use by the plants.

The SECRETARY. Do all soils contain available sulphates?

Mr. FAIRLIE. There may be soils which contain no sulphates at all.

Mr. MUNN. Will the additional supply of sulphur due to the expiration of certain patents bring a big enough production of sulphur so that sulphur from that source will in any way or to any great extent displace sulphur from pyrites in the manufacture of sulphuric acid and fertilizer?

Mr. FAIRLIE. I should expect that it would. Of course only time can answer that question definitely, but my personal opinion is that I can answer the question in the affirmative.

The SECRETARY. Can you give us any information as to the proportion of sulphuric acid made as a by-product from smelters and so forth, using pyrites, and the proportion of acid made directly? For instance, at Ducktown it is the by-product of the smelting operation.

Mr. FAIRLIE. There is a large amount of acid made as a by-product from smelting zinc ore. The production of by-product acid, made at copper smelters, compared with the total production in the United States was, for 1917, about 8 per cent. The total production of by-product acid, including that made at zinc smelters as well as that of copper smelters, was in 1917 about 26 per cent. of the total output for the United States.

Dr. SMITH: The questions which Dr. Olsen asked, and which you touched on are ably discussed in the writings of Cyrus W. Hopkins, former agricultural expert of the University of Illinois, who died recently. His writings go into this matter of the use of raw phosphates very fully as well as the cultivation of the soils to get the best results.

USE OF ROSIN IN PAINT AND VARNISH

By MAXIMILIAN TOCH

Read at the Savannah Meeting, Dec. 3, 1919

As far back as any man in the paint or varnish industry can remember, rosin has not only been despised, but its general use has been discouraged by paint chemists, and endless numbers of tests have been devised so that as a paint or varnish material its use has been discouraged. In addition to that, manufacturers have always been more or less ashamed to acknowledge that they have used it; and, so far as I am personally concerned, I have never been a believer in it, excepting for the manufacture of resinates as driers, because up to within a few years ago no rosin varnish, or paint oil containing rosin, has been made which has had much merit.

I do not wish to prolong this paper unduly by citing the enormous number of specifications in existence, all of which discourage the use of rosin but, suffice it to say, that up to 1914 there was hardly a paint or varnish specification, that I know of, that did not read similar to the following specifications which I quote:

CABINET RUBBING VARNISH

Composition:

1. To be made exclusively from the best grade of hard-varnish resins, pure linseed oil, pure spirits of turpentine, and lead-manganese driers, and be free from all adulterants or other foreign materials.

PAINT DRIER

Composition:

2. To be composed of lead, manganese, or cobalt, or a mixture of any of these elements, combined with pure linseed oil and hydrocarbon solvent, and to be free from adulterants, sediment, and suspended matter. Resins other than rosin may also be used at the option of the manufacturer.

JAPAN DRIER

To be made of varnish gums, linseed oil, turpentine and lead and manganese driers.

Common rosin, benzine and similar adulterants must be absent.

SPAR VARNISH

Composition and Quality:

2. Spar varnish shall be made exclusively from the best grade of hard varnish resins, pure linseed oil, pure spirits of turpentine and lead-manganese or cobalt driers, and shall be free from all adulterants or other foreign materials.

It is not my intention to go deeply into the chemistry of rosin, because the material is well-known and ha s specific characteristics. Suffice it to say, that rosin is obtained from the sap of certain species of pine trees. This sap is collected by scarifying the tree and collecting the sap, which solidifies under the name of Gum Thus. When this Gum Thus, which is a yellow, viscous, semi-hard and waxy looking material, is distilled it yields turpentine by condensation and rosin remains behind.

Rosin is a brittle resin, which ranges in color from a pale yellow glass-like looking substance to a very dark brown, almost black solid gum. It melts very readily and is practically fluid at the temperature of boiling water. Under ordinary circumstances, when converted into a paint oil or into a varnish, it turns white when subjected to even slight moisture and becomes friable and rubs off very readily when even slight friction is applied. It is so highly acid that lead and zinc, or other basic pigments, cannot be mixed with it, for it forms resinates so rapidly that the resulting material "livers," or becomes semi-solid or gelatinous before it can be entirely applied or consumed. It does not stand water, and when used as a furniture varnish it becomes soft and sticky on a rainy day; and, all in all, it has been regarded as a totally unfit material for paint or varnish purposes. Yet, the great reason for its use has been that there is nothing like it so low in price, which, consequently, made it a ready adulterant for the higher priced and better resins.

Speaking again of the specifications which prohibited its use, I recall a case some years ago where a manufacturer furnished, under a Government specification, a large quantity of spar varnish for boat use, and the specification read that the varnish was to be

composed of fossil or semi-fossil resins reduced with linseed oil and a proper solvent and drier. The varnish was delivered and was rejected, because it gave the Liebermann-Storch color reaction for rosin.

Rosin may be detected by means of the Liebermann-Storch color reaction. A deep reddish-violet coloration is produced in the presence of 1 to 2% of rosin. The reaction is also given by rosin oil.

The manufacturer contended that he did not put rosin in the varnish as an adulterant, and the Government claimed that the specifications had been violated; and, in order to settle this matter and prevent a law-suit, the Government selected me as an arbitrator and the manufacturer did the same. On investigation, I found that a very small percentage of rosin had been used to "grease the kettle" in order to prevent the discoloration of the fossil resin in the melting, and I therefore decided in favor of the manufacturer. But this, and many other examples that I could cite, indicate that rosin as a paint material, and more particularly as a varnish compound, has been largely discouraged for the reasons that I have cited:

First.—Because it is no good, and

Second.—Its price had been so low that it was used as an adulterant or a cheapening material.

But the advent of China wood oil has brought about a change, and I am unafraid to admit that, while I despised and discouraged the use of it in my own factory, I am now a firm believer in it; and, until something better can be discovered, rosin has at last come into its own.

Let us remember that fifteen years ago China wood oil was condemned because its physical characteristics were compared with linseed oil, which shows us that it is a mistake to take a new material and judge it by an older one.

Raw linseed oil, as everyone knows, dries with the aid of a drier, and when suitably mixed with the proper pigments forms a film which lasts anywhere from three to eight years, even under extreme exposure.

Raw China wood oil, no matter what it is mixed with, dries with an opaque, brittle, crystalline film, which is neither flesh nor fowl. It polymerizes or solidifies when heated for twenty minutes to 420° F. It is difficult to manipulate and in unskilled hands it is

a failure. But, when four pounds of China wood oil are heated with one pound of rosin that has been partially or wholly converted into a resinate of lead, or similar compound, the heat can be carried up to 600° F. without danger of the polymerization of the oil, and a varnish is obtained which, while fairly high in acid number, possesses more remarkable qualities than the best Kauri linseed oil varnish ever made. This sounds strange, but it is true.

Of course, to those skilled in the arts it is known that this resultant fusion of five pounds just mentioned must be diluted with equal quantities of turpentine or turpentine substitute, and the film so produced will not turn white after it has been permitted to dry thoroughly, even though the test sample is placed in water for weeks. When I made my first experiments along these lines I did not use the material as a varnish, but I used it as a paint oil. Of course, lead and zinc could not be used as bases, because chemical union would take place, and the compound, which I called a tungo resinate of lead or zinc, was formed, which was a viscous, ropy, gelatinous material, physically unfit for making paint ready for use. But, if the proper pigments were selected, such as graphite, lithopone, red oxide and blanc fixe, a paint could be made which remained in suspension for a long time.

As many know, I do not rely upon laboratory experiments for the finding of my conclusions; but, in 1915 and 1916 I made several hundred gallons of various colored paints, omitting linseed oil entirely as a vehicle, and substituting for it a varnish made from rosin and China wood oil, and these paints I applied to wooden structures on the Atlantic Coast which were from one hundred to five hundred yards distant from low tide and subject, therefore, to the heavy sea fogs of that locality. In comparison with these tests there were a number of smaller buildings painted with various mixtures of lead and zinc and linseed oil, and the conclusions arrived at were that the gloss and hardness of the resulting film, after three years, was as good for the rosin-China wood oil mixture as for the linseed oil paint, with this exception—that the rosin-China wood oil paint left a better surface for repainting as it perished.

Rosin forms esters with certain alcohols like glycerine and phenol, in which the rosin acts as the base and the alcohol as the acid; so that, under certain circumstances, if we follow the experiments of Schall and use a silver-lined or aluminum kettle, we get a glyceride of rosin which is soluble in China wood oil at tempera-

tures up to 600° F., and the resultant varnish has a very low acid number ranging between 7 and 15, which makes it more suitable for mixtures with lead and zinc. But, used alone, rosin esters produce waterproof varnishes, which are, so far, superior to the linseed oil fossil resin varnishes that the newer specifications of the Government not only permit their use, but encourage it, and I herewith quote a specification used by the Railway Commission and other branches of the Government service, which shows that the material in question is bought in large quantities:

It must be resistant to air, light and water. The manufacturer is given wide latitude in the selection of raw materials and processes of manufacture, so that he may produce a varnish of the highest quality. Preference will be given to rapid drying varnishes.

FLAT FINISH INTERIOR WALL PAINT

The paint supplied must be ready for use for finish coat work. There shall be present not less than 65 or more than 70 per cent of pigment. The vehicle must be composed of treated oils and volatiles, or varnishes which produce a satisfactory washable flat finish.

DECK AND FLOOR PAINT

The vehicle shall consist of linseed oil and sufficient waterproof varnish to give the paint a high gloss and resistance to abrasion and water. The varnish in the paint shall conform to the general specifications for varnish.

SPAR VARNISH FOR USE IN AIRPLANE CONSTRUCTION *

The manufacturer is given wide latitude in the selection of raw materials and processes of manufacture so that he may produce a varnish of the highest quality. Rapidity in dust-free drying and final hardening is essential.

It may interest the public to know that nearly all automobiles are varnished nowadays with varnish of this type. There again, I have conducted a large series of experiments, having painted and varnished no less than twenty automobiles in the last four years with this particular type of varnish, and while I have brought no illustrations with me, I have the record of one particular automobile which, after one year of hard service in all kinds of weather, is still brilliant and glossy and does not need revarnishing. Rain, sleet or snow has no effect on a varnish of this type and does not produce

* Spar Varnish and Railway Varnish are now alike in specification.

the well-known bloom or bluish spots so familiar to those who use linseed oil varnish.

Since the War the price of rosin has risen until it is to-day such a high-priced material that we will not frown down upon it on account of its low price and poor quality. Human nature is very peculiar with reference to the embrace of materials which once were despised and come under the category of that well-known stanza in Pope's "Essay on Man:" "We first abhor; then pity; then embrace."

Every one of use can remember when the metal platinum was only used in the laboratory because of its insolubility and high melting point. Its price when I was a student was about one-third that of gold, or even less. As the price rose and it became a really expensive material, two and a half times dearer than gold, it was fashionable to use it as a setting for diamonds, even though its color was leaden and the polish that it took soon dimmed. Now that platinum is worth five times more than gold, it is idolized by the rich only on account of its price.

Turpentine has always been regarded as the ideal paint solvent, and specifications, tests and laws have been made to prevent the adulteration of turpentine with the petroleum products. Yet, in 1911, the price of gasolene in Italy was twice that of Turpentine. Furthermore, there was no tax on turpentine, but there was one on gasolene, and it was a criminal offense in Italy to adulterate gasolene with turpentine.

A hundred and fifty years ago when a good slave was sold in the South, particularly along the Coast, the deed usually recited that the slave must not be fed on terrapin, which, as you know, is a species of turtle that was once so abundant that it was even despised by the negroes as food. But, when the animal became rare, and finally a small portion of it—hardly more than one hundred grammes—sold in restaurants for $3.50, only the elect few and the newly rich regarded it as fashionable to eat terrapin.

Five years ago rosin sold at about two cents a pound and to-day it has gone to ten cents a pound. As labor and materials and its legitimate use will raise its price, who knows but what some day it will be considered criminal to adulterate rosin with the fossil resins of the Orient?

DISCUSSION

Mr. Richter. I would like to ask Dr. Toch whether in drying processes with the wool oil there is some oxidation takes place in the wood oil during the drying?

Dr. Toch. I ame very frank to confess I don't know, and I don't think anybody else does, either.

The Secretary. That is a good subject for investigation which I am going to take up, and perhaps I can let you know in a year or two.

Edward Bartow.

AN ANALYSIS OF THE EXPLOSION PROCESS OF RECOVERING THE SODA SALTS FROM BLACK LIQUOR

By HUGH K. MOORE

Read at the Savannah Meeting, Dec. 3, 1919

At our Buffalo meeting in 1917 I read before this Institute a paper entitled "Chemical Engineering Aspect of Renovating a Sulphide Mill." In this paper I mentioned a new method of recovering alkali from the black liquor of the so-called sulphate process. In the new method as outlined in the above paper I mentioned some of the inherent difficulties. I showed that, while it was theoretically possible to evaporate the 50 per cent liquor to dryness, ignite and burn it without the addition of extraneous fuel, it was not practical at that time because no method had been evolved by which the liquor could be subdivided to that minuteness necessary for this operation to take place.

If you recall, this liquor was being atomized by a blast of high pressure air with atomizing nozzles developed to a state of high efficiency by years of constant experimenting, and that, owing to the velocity imparted to it by the high pressure air, it was traveling like the shot out of a gun. The landing place for this liquor was only some feet away, and yet 50 per cent of it had to be evaporated and the remainder ignited in this infinitesimally small part of a second.

It was also brought out that, without extraneous sources of heat, this liquor was not evaporated and ignited, but that it landed on the fire, plastering it over and putting it out. It was also brought out that it was not lack of sufficient heat in the furnace, but that there was no means of transmitting the required heat to the flying particles at such a rate as to evaporate the water and ignite the remainder while in transit.

We showed how we made use of Stefan's Law which, in brief, is that the heat radiated from one black body to another is as the difference of the fourth powers of the absolute temperatures. This may be expressed as follows:

$$E = K(T^4{}_2 - T^4{}_1)$$

where E is the total energy radiated, T_2 and T_1 being absolute temperatures, T_2 being the higher.

Putting this into tangible form we get this formula:

$$\text{B.T.U. radiated per minute} = 2 \cdot 66 \times 10^{-11}(T^4{}_2 - T^4{}_1).$$

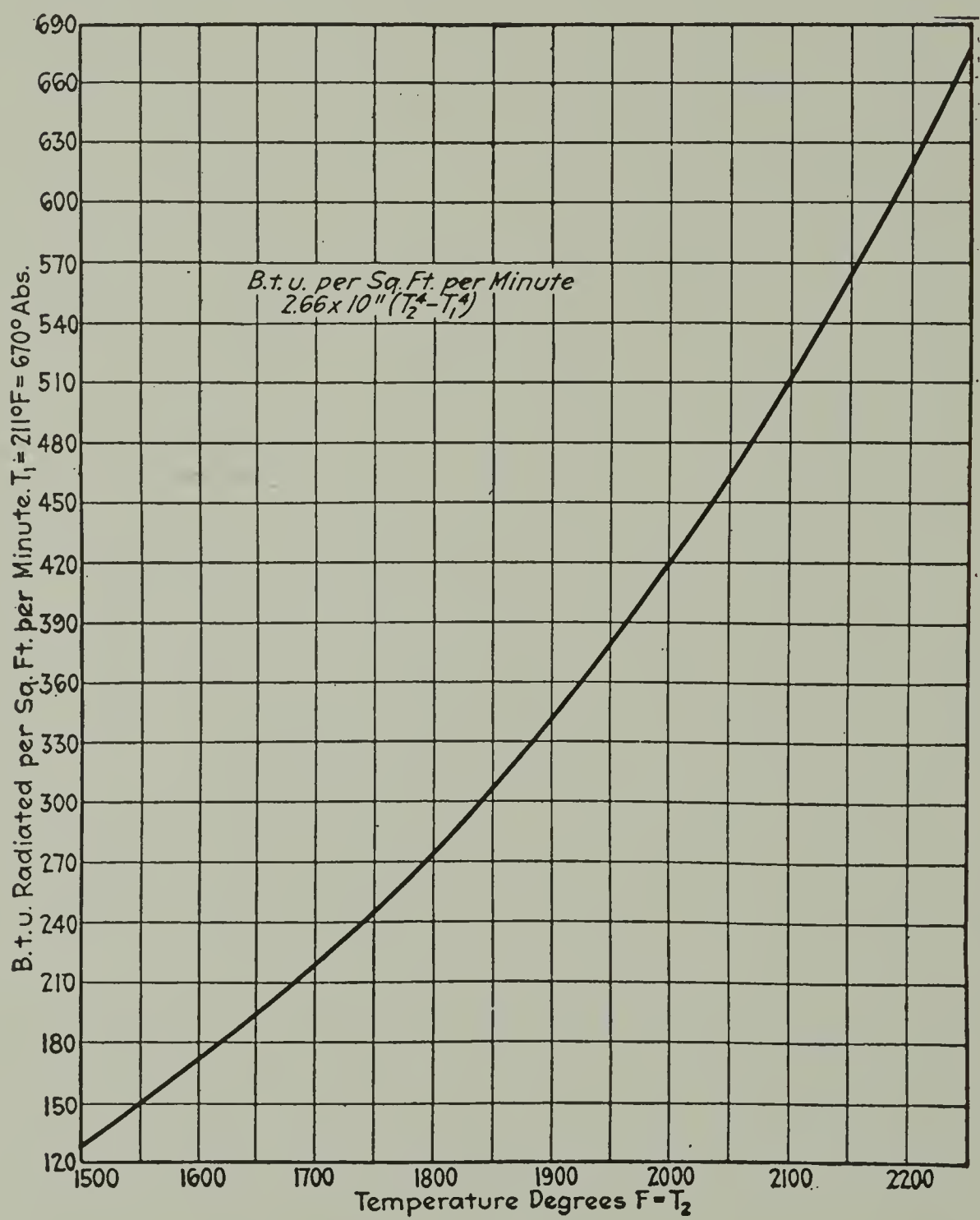


CHART A.

Table I shows the B.T.U. radiated per square foot per minute at different temperatures according to Stefan's Law.

Table II shows B.T.U. radiated per square foot from black bodies at different temperatures to bodies at 211° F.

Chart *A* shows this in graphical form.

TABLE I

HEAT RADIATED PER SQ. FT. PER MIN. STEFAN'S LAW FOR BLACK BODIES. ENGLISH UNITS.

$K = 2.66 \times 10^{-11}$. B.T.U. $= K(T^4_2 - T^4_1)$ per min.

$T_1 = 500°$ abs.		$T_1 = 600°$ abs.		$T_1 = 700°$ abs.		$T_1 = 800°$ abs.		$T_1 = 900°$ abs.		$T_1 = 1000°$ abs.		$T_1 = 1100°$ abs.	
T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.
0	9.2	800	7.4	800	4.5	800	....	800	....	800	....	800	....
900	15.8	900	14.0	900	10.5	900	6.5	900	....	900	....	900	....
1000	24.9	1000	23.1	1000	20.2	1000	15.8	1000	9.15	1000	....	1000	....
1100	38.2	1100	35.5	1100	32.0	1100	28.7	1100	21.5	1100	12.3	1100	....
1200	53.5	1200	51.7	1200	48.8	1200	44.3	1200	37.8	1200	28.6	1200	16.3
1300	73.9	1300	72.1	1300	68.7	1300	64.7	1300	58.2	1300	49.0	1300	36.6
1400	100.4	1400	98.8	1400	95.7	1400	91.2	1400	84.7	1400	75.5	1400	63.2
1500	133.0	1500	131.3	1500	127.7	1500	123.8	1500	117.2	1500	107.4	1500	95.7
1600	172.5	1600	171.0	1600	167.9	1600	163.0	1600	156.8	1600	147.5	1600	135.4
1700	220.5	1700	216.0	1700	215.2	1700	211.2	1700	204.6	1700	195.4	1700	183.1
1800	278.0	1800	276.0	1800	273.0	1800	268.0	1800	261.9	1800	252.5	1800	240.4
1900	342.0	1900	340.2	1900	336.8	1900	332.8	1900	326.2	1900	217.1	1900	304.9
2000	424.0	2000	422.0	2000	419.0	2000	414.0	2000	408.2	2000	399.0	2000	386.8
2100	515.8	2100	514.0	2100	510.4	2100	506.5	2100	499.9	2100	490.8	2100	479.4
2200	621.5	2200	619.5	2200	616.0	2200	612.0	2200	605.6	2200	596.4	2200	583.9

TABLE II

HEAT RADIATED PER SQ. FT. PER MIN. STEFAN'S LAW FOR BLACK BODIES. ENGLISH UNITS

$K = 2.66 \times 10^{-11}$. B.T.U. $= K(T^4_2 - T^4_1)$ per min. $T_1 = 670$ abs. $= 211°$ F.

$T_1 = 670°$ abs.		$T_1 = 670°$ abs.		$T_1 = 670°$ abs.		$T_1 = 670°$ abs.		$T_1 = 670°$ abs.	
T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.	T_2	B.T.U.
800	5.5	1100	33.6	1400	96.7	1700	216.7	2000	420.3
900	12.1	1200	49.9	1500	129.3	1800	273.8	2100	511.8
1000	21.2	1300	70.2	1600	172.9	1900	338.3	2200	617.6

It will be remembered that we tried crude oil, but found that with oil we had the coldest zone where we needed the hottest fire. We tried powdered coal, but found that in addition to the usual difficulties the impurities in the coal not only used up our soda, but

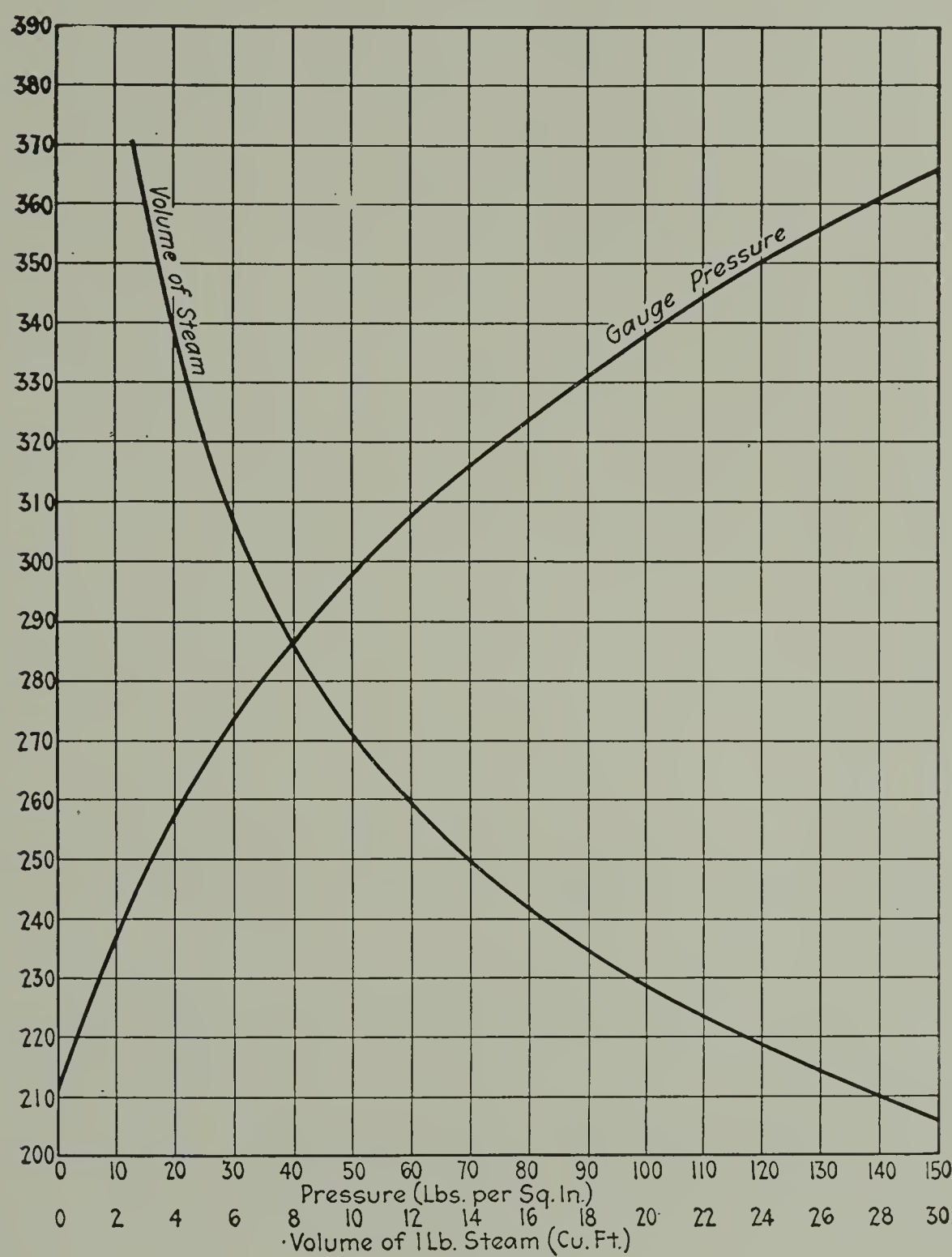


CHART B.

also prevented rapid settling in our causticizing tanks. We finally adopted producer gas of such a quality as should contain the maximum amount of illuminants. These illuminants radiated heat to the flying particles of black liquor.

At this time I did not attempt to show the square feet of

radiating surface in these particles and consequently did not go into the subject as to the magnitude of effect of the radiant heat. We had certain data which we did not care to make public first, because they were only an approximation, and secondly, because we were conducting further experiments and did not want to draw other people's attention to these investigations.

Our experiments have been crowned with success, though we have not as yet carried them to their logical conclusion. The process based on these experiments has superseded the process described in the previous paper and is being developed to its logical conclusion as fast as we can get apparatus and equipment. In this new development we operate without using any extraneous fuel and net a large boiler horse power. After having spent much money and many years experimenting on atomizers for this liquor we finally decided that any further experiments along this line were a waste of time and money and so discontinued them. We started a new series of experiments, however, the effect of which was to disrupt these fine particles by a force contained therein and thus not only expose more surface to the hot furnace gases, but also form more surface which, if ignited, would radiate more heat to other particles in transit which had not reached the dehydrated stage.

Of course the cheapest source of explosion is in steam.

Table III gives data from Marks & Davis Steam Tables, giving the volume of steam and pressures at different temperatures, and Chart B shows these data in graphical form.

TABLE III

STEAM PRESSURES AND VOLUMES OF ONE POUND OF WATER AT DIFFERENT TEMPERATURES

Temperature F.	Gauge Pressure.	Volume in Cubic Feet.	Temperature F.	Gauge Pressure.	Volume in Cubic Feet.
211	.98	27.29	310	63	5.62
220	3	23.15	320	75	4.91
230	6	19.39	330	88	4.306
240	10	16.32	340	104	3.787
250	15	13.82	350	121	3.342
260	20	11.76	360	138	2.957
270	27	10.06	370	158	2.627
280	35	8.64	380	181	2.340
290	43	7.46	390	205	2.089
300	52	6.46	400	332	1.872

If you refer to Chart B you will observe that at the low pressures that 1 lb. of water occupies many cubic feet when changed to steam. Thus at 249° F. 1 lb. of steam occupies 14 cu. ft. If we consider 27.65 cu. in. to the pound we have one volume of water expanding to 874 times its original volume. The altitude of La Tuque is about 560 ft. above sea level and the boiling-point of water is 211° F. Consequently as the work of which I am going to speak of was done at La Tuque, the figures which are given in this paper refer to an altitude of 560 ft. above sea level with the corresponding boiling-point of water of 211° F.

Referring again to Chart B it will be seen that 1 lb. of steam at 211° F. occupies 27.29 cu. ft., and consequently occupies 1703 times its original volume.

If now we can heat this liquor sufficiently and maintain pressure higher than those required for the corresponding temperatures, we can then prevent evaporation and yet store energy in the liquor. If now the pressure upon this liquor is released suddenly, we should have an explosion corresponding to the ratio between the steam formed and the liquor left.

In order that we may bring this into concrete form I am going to give now the data I shall use in future calculations:

BLACK LIQOUR

Per cent water		44.7
Per cent total solids		55.3
Specific gravity of dehydrated black liquor	15° C.	2.029
Specific gravity of wet black liquor	15° C.	1.39
Specific gravity of smelt	15° C.	2.21
Specific heat dehydrated black liquor		.56
Specific heat of smelt from 0 to 100° C.		.52
B.T.U. in 1 lb. of smelt		525

Quantity of heat $N = (.2405 + .000019t)t$
Quantity of CO_2 $= (.19 + .00006t)t$
Quantity of O $= (.2104 + .0000187t)t$
Quantity of CO $= (.2405 + .000019t)t$
Quantity of steam $= (.42 + .000103t)t$

Capacity of furnace, clean	294 cu. ft.
Capacity of furnace, operating	327 cu. ft.
Area of inside surfaces	273 sq. ft.
Cubic feet gas operating conditions going through furnace per min	55,000
Length of time it takes a particle to travel from nozzle to exit of furnace	.32 second

Average volume liquor blown in per min	1.13 cu. ft.
Ash in 1.13 cu. ft.	22.7 lbs.
Analysis of flue gases CO_2	15.0 per cent
CO	.6 per cent
O_2	3.3 per cent
N_2	81.1 per cent
Temp. furnace under running conditions	1950° F.
Temp. of smelt at bottom	1600° F.

Dry black liquor occupies 13.62 cu. in. per lb.
Water occupies 27.65 cu. in. per lb.
Latent heat 1 lb. water at 211° 971.3
B.T.U. per pound of dry black liquor as it enters furnace = 5080 B.T.U.

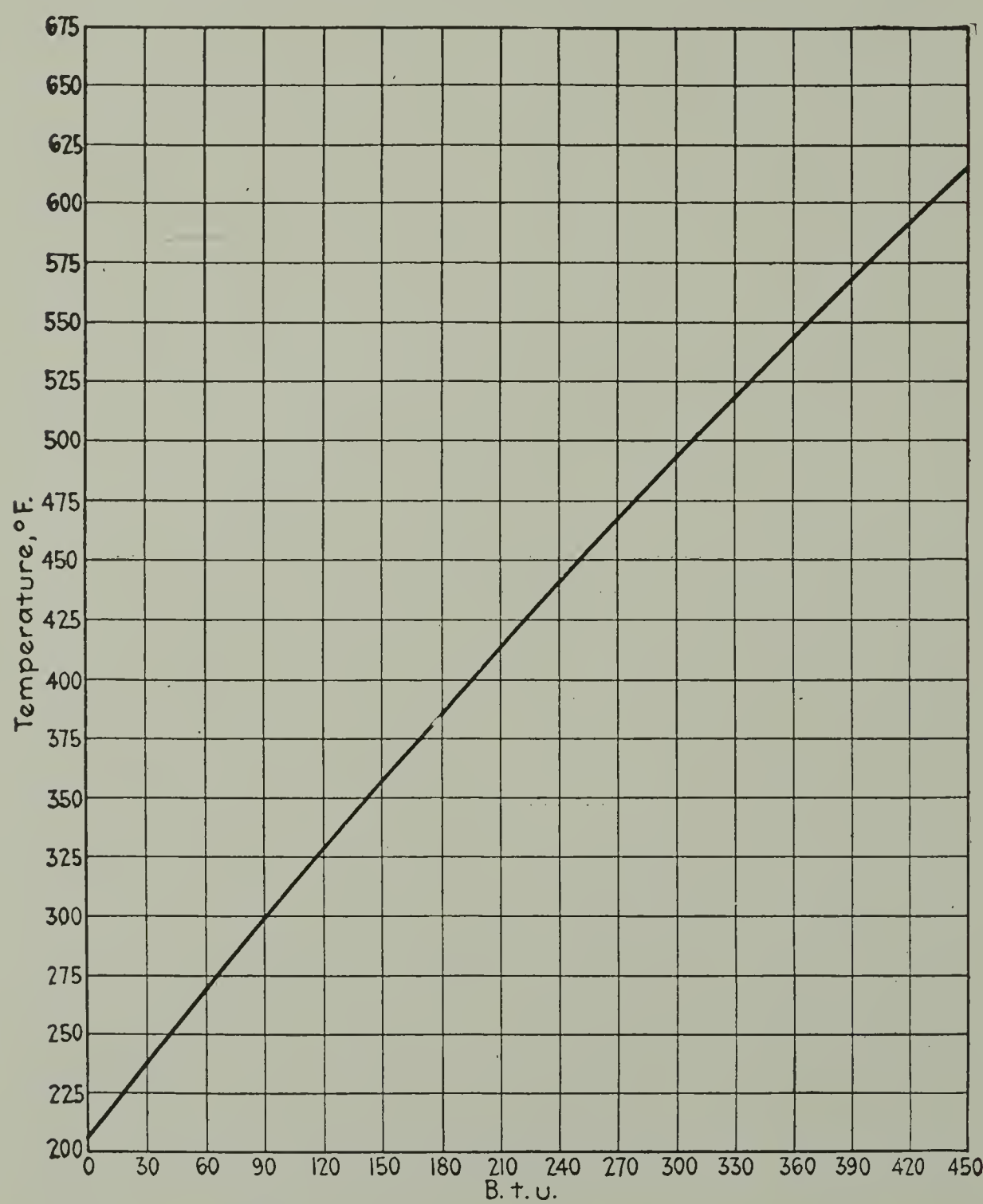


CHART C.—Showing B.t.u. from One Pound of Water Available for Formation of Steam at 211° F.

Table IV, based on Marks & Davis Steam Tables, illustrated by Chart C, shows the number of B.T.U. available for explosion at 211° F. of 1 lb. of water heated at different temperatures with the pressures maintained above said temperatures according to Chart B.

TABLE IV

HEAT IN HOT WATER AVAILABLE FOR FORMATION OF STEAM AT 212° F.

Temp.	B.T.U.	Temp.	B.T.U.	Temp.	B.T.U.	Temp.	B.T.U.	Temp.	B.T.U.	Temp.	B.T.U.
211	0	280	70.0	350	142.4	420	216.4	490	214	560	375
220	9.1	290	80.3	360	152.9	430	227.2	500	305	570	387
230	19.2	300	90.6	370	163.4	440	238.0	510	317	580	399
240	29.3	310	100.9	380	173.9	450	249.0	520	328	590	412
250	39.5	320	111.2	390	184.5	460	260.0	530	340	600	425
260	49.6	330	121.6	400	195.1	470	271	540	352	610	
270	59.8	340	132	410	205.7	480	283	550	363	620	

Once more, even at the risk of being tedious, I want to emphasize that the pressures *must* be maintained according to the temperature, so that not the slightest evaporation can take place.

Chart D shows graphically the explosive ratio of liquor at different temperatures according to Table V.

The specific heat of the dry liquor is .56 and that of water is of course 1. An explanation of what I mean by explosive ratio may be in order. Thus at 360° F. at a pressure over 138 lbs. per sq. in. we liberate from 1 lb. black liquor 115.8 B.T.U., when the pressure is reduced to a barometer of 29.33 ins. mercury. This liberates .1191 lb. of steam, which in a liquid state occupied 3.29 cu. ins.; 1 lb. of black liquor occupies 19.89 cu. ins. The difference 16.60 cu. ins, is occupied by the remaining liquor. Now .1191 lbs. of saturated steam at 211° F. occupies 5611 cu. ins. and this divided by 16.60 gives 338.1, which is the explosive ratio. The explosive ratio is quotient obtained by dividing the volume of steam formed by the volume of the residual liquor.

It will be observed from a study of Table V and Chart D that the pressure increases at a greater rate than the explosive ratio. But this is a matter which I do not intend to go into in this paper, as we have not yet determined at what point the increased efficiency is counterbalanced by the power and costs of maintaining increased pressures.

TABLE V

Table Showing Explosive Effect of Black Liquor at Different Temperatures

Basis is 1 lb. Black Liquor, Sp. Ht. = .756. 1 lb. Black Liquor = 19.89 cu. in.

Temp. F.	B.T.U. in 1 lb. H_2O Available for Steam at 211 F.	B.T.U. Liberated 1 lb. Black Liquor.	Lbs. H_2O Changed to to Steam 211° F.	Cu. In. H_2O Changed to Steam 211° F.	Cu. In. in black liquor left after explosion 211° F.	Cu. In. of Steam Made at Explosion at 211° F.	Ratio Explosive $\frac{a}{b}$	Gauge Pressure.
211	0.0	0.0	0.0000	0.0000	19.89	000	00.00	0
220	9.1	6.9	0.0071	0.1959	19.79	334	16.88	2
240	29.3	22.1	0.0228	0.6308	19.26	1076	55.86	10
260	49.6	37.5	0.0386	1.0680	18.83	1821	96.70	21
280	70.0	52.9	0.0545	1.5070	18.38	2569	139.80	34
300	90.6	68.5	0.0705	1.9500	17.94	3326	185.50	52
320	111.2	84.1	0.0866	2.3940	17.50	4083	233.30	75
340	132.0	99.8	0.1028	2.8420	17.05	4846	284.30	103
360	152.9	115.8	0.1191	3.2910	16.60	5611	338.10	138
380	173.9	131.7	0.1354	3.7430	16.15	6368	396.20	181
400	195.1	147.9	0.1519	4.2000	15.69	7161	456.40	232
420	216.4	164.0	0.1685	4.6590	15.23	7945	521.80	294
440	238.0	180.3	0.1853	5.1240	14.77	8738	591.60	366
460	260.0	197.0	0.2024	5.5980	14.29	9545	668.00	451
480	283.0	214.4	0.2204	6.0990	13.79	10390	753.40	550
500	305.0	231.1	0.2374	6.5660	13.32	11190	840.70	664
520	328.0	248.5	0.2554	7.0620	12.83	12040	938.70	795
540	352.0	266.7	0.2740	7.5770	12.31	12920	1050.00	945
560	375.0	284.1	0.2919	8.0720	11.82	13770	1165.00	1115
580	399.0	302.4	0.3105	8.5900	11.30	14650	1308.00	1308
600	425.0	322.1	0.3309	9.1490	10.74	15610	1452.00	1525
620	453.0	343.3	0.3527	9.7520	10.14	16630	1646.00	1768

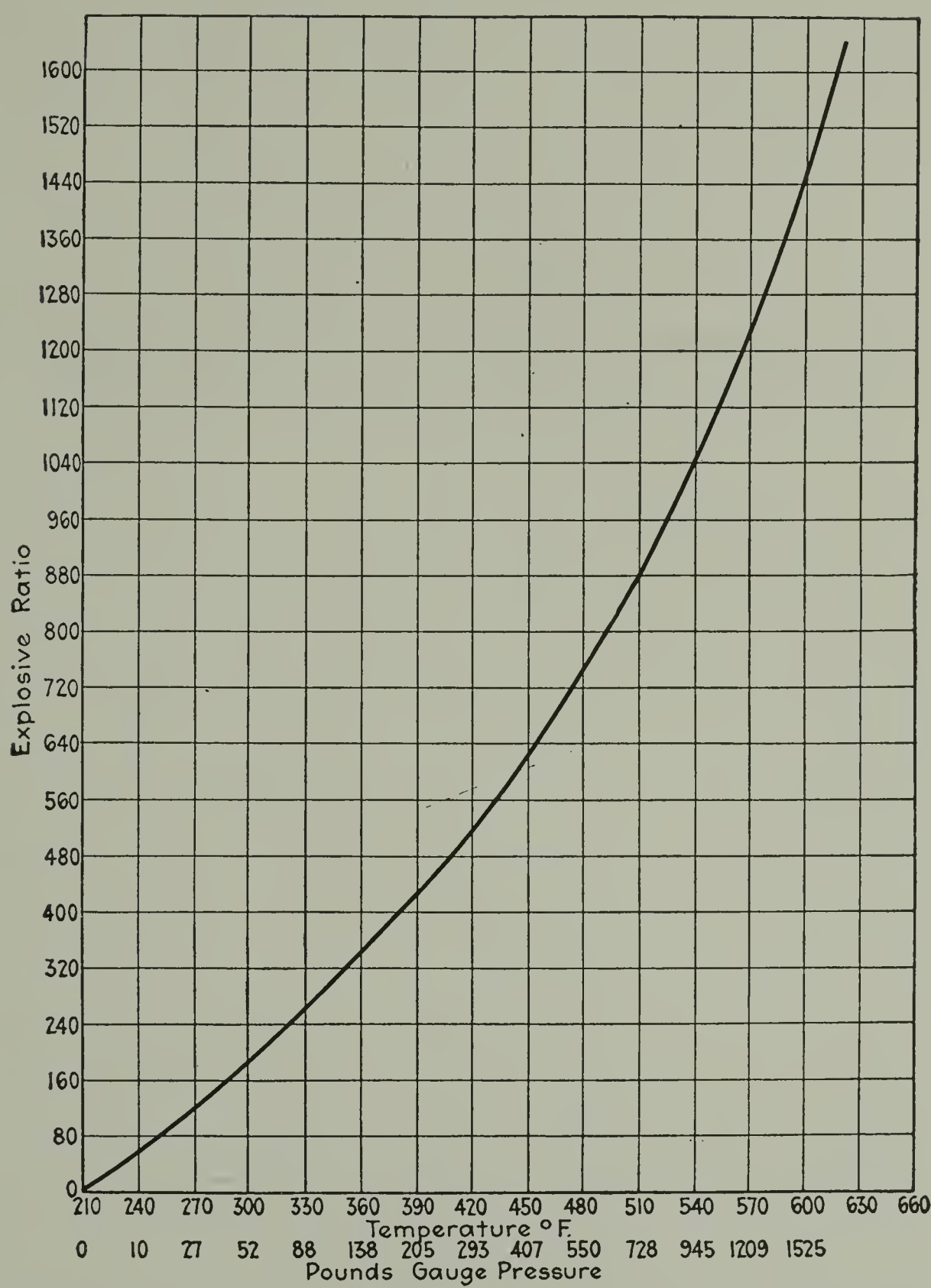


CHART D.—Explosive Ratio of Block Liquor at Different Temperatures and Corresponding Pressures. Explosion Takes Place at 211° F.

The general composition of pulp wood is as follows:

	Per Cent.
Cellulose	50
Carbohydrates	16
Lignin	30
Protein	·7
Resin and Fat	3·3

If we take out the cellulose the remainder of the wood, viz., that which goes into the black liquor, has the following composition:

	Per Cent.
Carbohydrates	32
Lignin	60
Protein	1.4
Resin and Fat	6.6

Now considering the carbohydrates in wood liquor and have a formula of $C_nH_{2n}O_n$ in which n is 5 or 6 we have this approximate composition:

	Per Cent.	
Carbon	40	Combined water, 60 per cent.
Hydrogen	6.7	Excess H_2 to H_2O, none
Oxygen	53.3	

If we assume Classon's formula for liquor, viz.,

$C_{38}H_{38}O_{11}C_{40}H_{42}O_{11} \cdot 2CH_2 \cdot O$, we get this approximate composition:

	Per Cent.		
Carbon	67.2	Combined H_2O	30.3
Hydrogen	5.9	Excess H_2 to H_2O	22.7
Oxygen	26.9		
		Total	53

In the same way we may take the following as the average composition of protein:

	Per Cent.		
Carbon	55.6	Combined water	25
Hydrogen	9.2	Excess hydrogen will burn to H_2O	58.3
Oxygen	13.0		
Nitrogen	22.2		
		Total	83.3

Even if the above is not correct, the error will be negligible on account of the small amount involved.

If we consider the resin of a formula $C_{10}H_{16}O$ we have an approximate composition of

	Per Cent.		
Carbon	79.0	Combined water	11.8
Hydrogen	10.5	Excess H to water	82.8
Oxygen	10.5		
		Total	94.6

Multiplying each by its percentage we get the results shown in Table VI.

TABLE VI

Substance.	Per Cent N	Per Cent C	Per Cent H	Per Cent O	Comb. H_2O	Per Cent Excess H	Total Water of Combustion.
Carbohydrates..	.00	12.80	2.14	17.06	19.20	0000	19.20
Lignin.....	.00	40.30	3.54	16.12	18.18	1.51	31.80
Protein.....	.18	.78	0.13	0.13	.30	.09	1.17
Resin.....	.00	5.21	5.21	0.69	.78	.61	6.24
Total.....	.18	59.11	6.50	34.21	38.46	2.21	58.41

It will be seen from the above that the residues from the wood after taking out the cellulose contains 59.11 per cent carbon. From data given we find that we have .269 lb. of organic matter, and we can also figure from .177 lb. carbonate that we have .0200 lb. of carbon therein, which corresponds to .0338 gm. of lignin liquor. Adding this to the organic matter we have .3029 lb. of organic matter; 59.11 per cent of this gives carbon present from 1 lb. black liquor, .1791 lb., of which .1591 lb. goes into the furnace gases, and .0200 lb. goes into sodium carbonate.

In ascertaining the heat in the liquor we assume that all the oxygen is combined with hydrogen and the residue hydrogen is calculated to burn with oxygen, giving 62,000 B.T.U. per pound of hydrogen burned. The carbon is calculated as giving 14,500 B.T.U. per pound when burned in the furnace. As to the carbon combined with the soda in form of carbonate we cannot give it 14,500 B.T.U. per pound, as it combines with the liquor in the digester to form lignin and rosin soap, acetates, etc. If we assign .6 of its value, viz., 8700 B.T.U. per pound, I think we shall have all the heat we are entitled to assume that we get from this source. Accordingly the .02 lb. C. in Na_2CO_3 would have 174 B.T.U. available as extra heat. If the formula given is correct for an average sample, our wood lignin (meaning all the wood but the cellulose) should contain 9560 B.T.U. per pound. Let us see if from other sources we can confirm this. This dry black liquor owing to its easy fusibility cannot be burned directly in a calorimeter. A sample was mixed with coal whose calorific value was known. Several determinations gave a value of 5080 B.T.U. per pound. If this value was used in the above tables we should have

a total heat in the liquor of 2809 B.T.U. instead of 2806 as given in Table IX.

Table VII from Gottlieb shows the composition of air-dry woods, though the B.T.U. per pound is figured on a bone-dry basis (air-dry woods contain 18 to 20 per cent moisture).

TABLE VII

ULTIMATE ANALYSIS OF AIR-DRY WOOD. CALORIFIC VALUE. BONE-DRY WOOD

Kind of Wood.	C	H	N	O	Ash.	B.T.U. per lb. Bone-dry Wood.
Oak.....	50.16	6.02	0.09	43.36	0.37	8316
Ash.....	49.18	6.27	0.07	43.91	0.57	8480
Elm.....	48.99	6.20	0.06	44.25	0.50	8510
Beech.....	49.06	6.11	0.09	44.17	0.57	8591
Birch.....	48.88	6.06	0.10	44.67	0.29	8586
Fir.....	50.36	5.92	0.05	44.39	0.28	9063
Pine.....	50.31	6.20	0.04	43.08	0.37	9153
Poplar.....	49.37	6.21	0.96	41.60	1.86	7834*
Willow.....	49.96	5.96	0.96	30.56	3.37	7926*

* Calculated.

According to this table if cellulose has 7720 B.T.U. per pound, 1 lb. of lignin (meaning all the constitutents of the wood but the cellulose) should have for fir 10,406 B.T.U., and 1 lb. of the lignin from pine should have 10,856.

I am inclined to think both these values rather high, at least for our woods. Table VIII shows data which we have determined experimentally. According to my observations we get the following results:

TABLE VIII

CALORIFIC VALUE OF SOME HEARTWOOD AND SAPWOODS

Kind of Wood.	B.T.U. per Bone-dry Lb.	Kind of Wood.	B.T.U. per Bone-dry Lb.
La Tuque spruce sapwood..	9,146	La Tuque jack pine sapwood..	9156
La Tuque spruce heartwood	9,076	La Tuque jack pine heartwood.	9386
La Tuque balsam sapwood..	9,766	Hemlock sapwood	8542
La Tuque balsam heartwood	10,535	Hemlock heartwood.....	8701
Cellulose (cotton).....	7,259	Cellulose (bleached pulp).....	7720
		Cellulose (unbleached pulp)...	7354

The above table is given because the average composition of wood does not apply to our mill at La Tuque. At La Tuque all the logs come from the river on a conveyor and they travel sidewise instead of lengthwise. A trap is arranged by which the large logs are dropped to another conveyor which goes to the sawmill. The slabs from the sawmill are composed almost entirely of sapwood, and they are used for making pulp after first having the bark removed in the debarking drums.

In Table IX we give the heat balance of a furnace in operation.

TABLE IX

HEAT BALANCE OF SMELTING FURNACE

Incoming Heat

B.T.U. of combustion 1530 lbs. carbon to CO_2	2218
*B.T.U. in .02 lb. carbon in carbonate	174
B.T.U. of combustion of .006691 H	415
B.T.U. of combustion .0062 lb. C to CO	27
B.T.U. coming in liquor at 285° F	192
B.T.U. in 2.05 lbs. air	50
	3076

*Carbon absorbed in smelt

Outgoing Heat

B.T.U. in 1 lb. liq. to 211° F	111
B.T.U. to evaporate .447 lb. H_2O to steam 211° F	514
B.T.U. required to raise .447 lb. steam to 1950° F	541
B.T.U. to evaporate .157 lb. H_2O at 211° F	153
B.T.U. required to raise .07 Na_2SO_4 to Na_2S_4	190
B.T.U. required to smelt .284 lb. soda salts	17
B.T.U. required to raise .5584 lb. CO_2 to 1950° F	140
B.T.U. required to raise .0146 lb. CO to 1950° F	335
B.T.U. required to raise .0146 lb. CO to 1950° F	7
B.T.U. required to raise .0892 lb. O_2 to 1950° F	43
B.T.U. required to raise 1.923 lbs. N_2 to 1950° F	989
	3040

It will be noticed from the above table that the outgo of heat, viz., 3040 B.T.U. per pound of liquor, nearly balances the income,

3076 B.T.U. of heat, and there has been no allowance made for radiation, which will be exceedingly small in this case, as all the furnaces but the end ones have no radiation of heat from the side

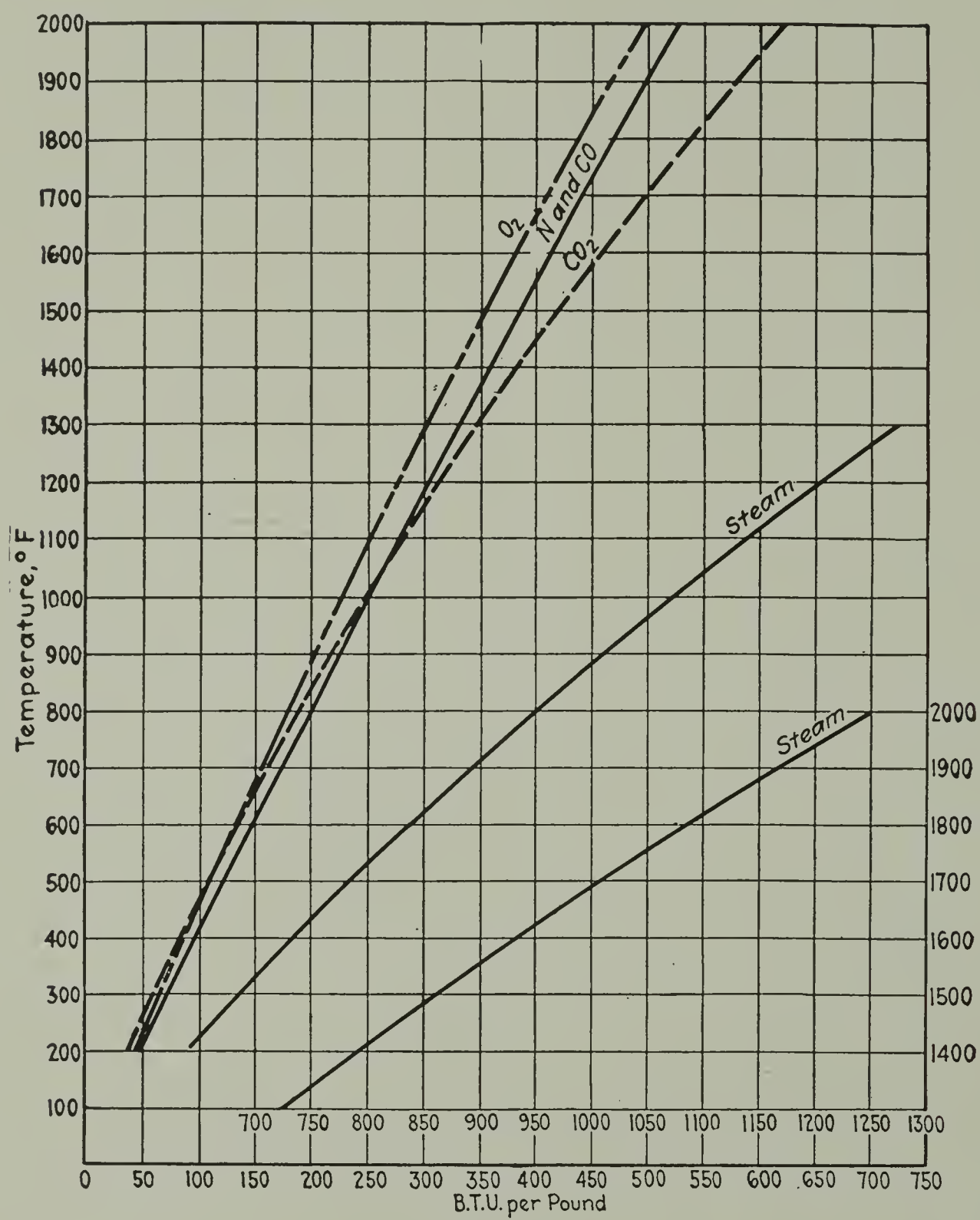


CHART E.

walls, i.e., the side walls of one furnace butts up against the side wall of adjoining furnaces.

In Chart E we show graphically the amount of heat contained in 1 lb. of nitrogen, carbon dioxide, carbon monoxide, oxygen + steam as calculated from data given at different temperatures.

The steam curve does not show the latent heat of evaporation any more than do the others. In Table X we have the data upon which Chart E is based.

TABLE X *

HEAT CONTAINED IN DIFFERENT GASES AT DIFFERENT TEMPERATURES. CALCULATED ACCORDING TO THE FOLLOWING FORMULAS:

$(.2405+.0000119t)t$ = B.T.U. for 1 lb. N
$(.19 \quad +.00006t)t$ = B.T.U. for CO_2
$(.2104+.0000187t)t$ = B.T.U. for 1 lb. O
$(.2405+.0000119t)t$ = B.T.U. for 1 lb. CO
$(.42 \quad +.000103t)t$ = B.T.U. for 1 lb. steam

Temp. ° F.	N	CO_2	O	CO	H_2O Steam.
200	48.5	38.23	42.8	58.5	212 °F. 93.6
400	98.1	85.6	87.1	98.1	184.5
600	148.6	135.6	132.9	148.6	289.1
800	200.0	190.4	180.3	200.0	401.9
1000	252.4	250.0	229.1	252.4	523.0
1200	305.6	314.5	279.4	305.6	652.4
1400	359.9	383.6	331.1	359.9	790.0
1600	415.3	457.6	384.4	415.3	935.4
1800	470.3	536.4	439.2	470.3	1090.0
2000	527.6	620.0	496.0	527.6	1252.0

* To accompany Curve Chart E

With the foregoing data at hand I will now describe the main elements in the process as now carried out. This process, for lack of a better name, is designated as the Explosion Recovery Process. Before doing so in order that the difference in the process may be clearly understood I submit diagrams 1, 2 and 3, illustrating the process which the explosion process superseded. The process shown in Diagrams 1, 2 and 3 had superseded in our mill the older processes, consisting of a Porian evaporator, incinerator, smelting furnace, and dissolving tank as its main constituents. Diagrams 1, 2 and 3 are portions of those in U. S. Patent No. 1137780, dated May 4, 1915, and for a detailed description you are referred to this patent. In brief producer gas comes through main 114, entering furnace through pipe 116, air from 2 to 5 lbs. pressure per square inch comes from main 117 and enters furnace through pipe 120. Black liquor enters mixing tank 121, where it is mixed with salt-cake and enters furnace through pipe spout 127, from

which it is atomized by air at high pressure through slot 128. The smelted liquor runs from spout 106 to dissolving tank 107, while the products of combustion pass under and through boiler 109 through from 112 and precipitator 113 to the stack. In the patent mentioned 113 is called a washer, but since this patent was taken out we installed a Cottrell Precipitator, manufactured by the Western Precipitation Company.

In Diagram 3, 140 is a burner atomizing oil. This process preceded the one shown in Diagrams 1 and 2. It will be observed from the above diagrams that the gas or oil is below the air supply and thus causes a reducing atmosphere.

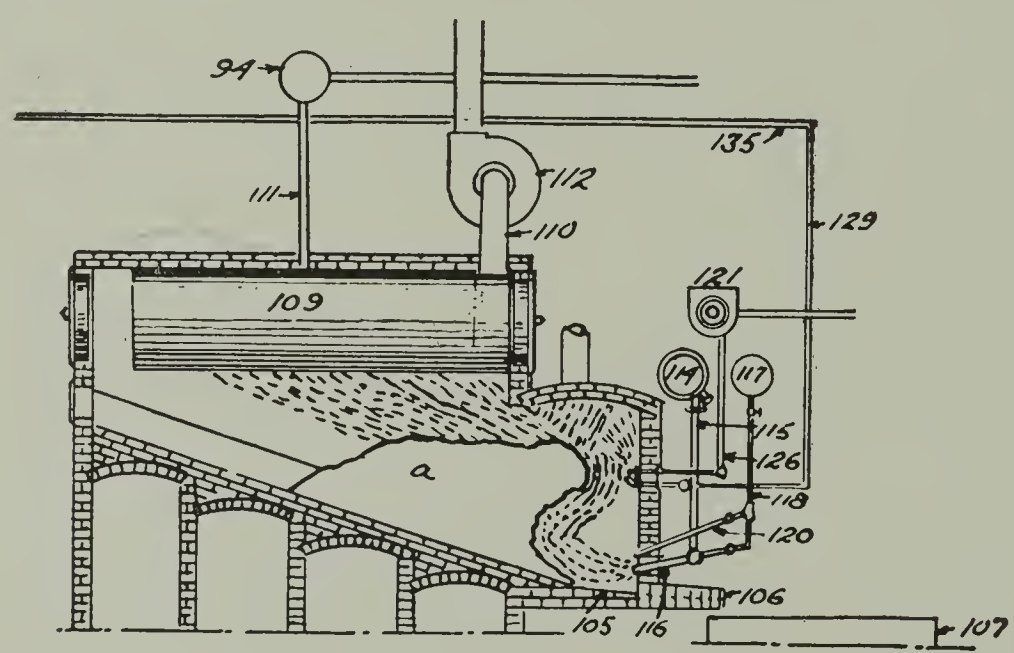


Diagram 1.

In the new process or explosion process as we call it we use no extraneous fuel.

Diagram 4 shows the main principles of the new process. I shall describe this as briefly as possible. For those wishing a more detailed description I refer them to the above patent.

In the Explosion Process, Diagram 4, the black liquor having been mixed with salt-cake in a mixer tank goes through pipe 8, pump 9, through pipe 10, tee 11, pump 12, heater coil 14, pipe 16 and manifold 20. From manifold 20 part of the liquor goes to the furnaces through pipe 19, terminating in nozzle. The remainder of the liquor goes through pipe 20 to pump 21, pipe 22, check valve 221, tee 11, pump 12, and so on through the cycle. In practice pump 9, 12 and 21 are combined in a four-stage single pump in which the first two stages take the place of pump 9, while the

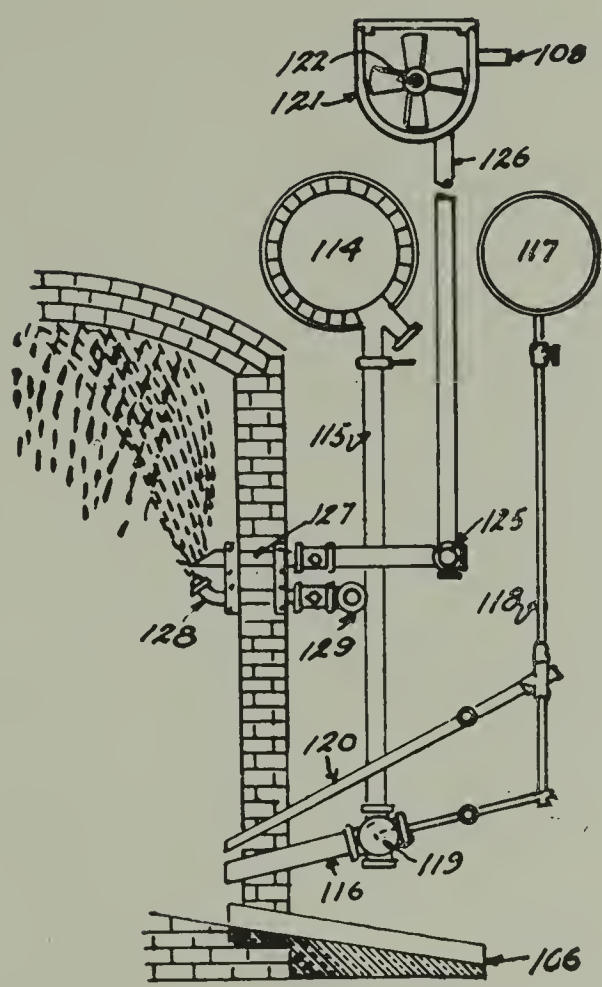


DIAGRAM 2

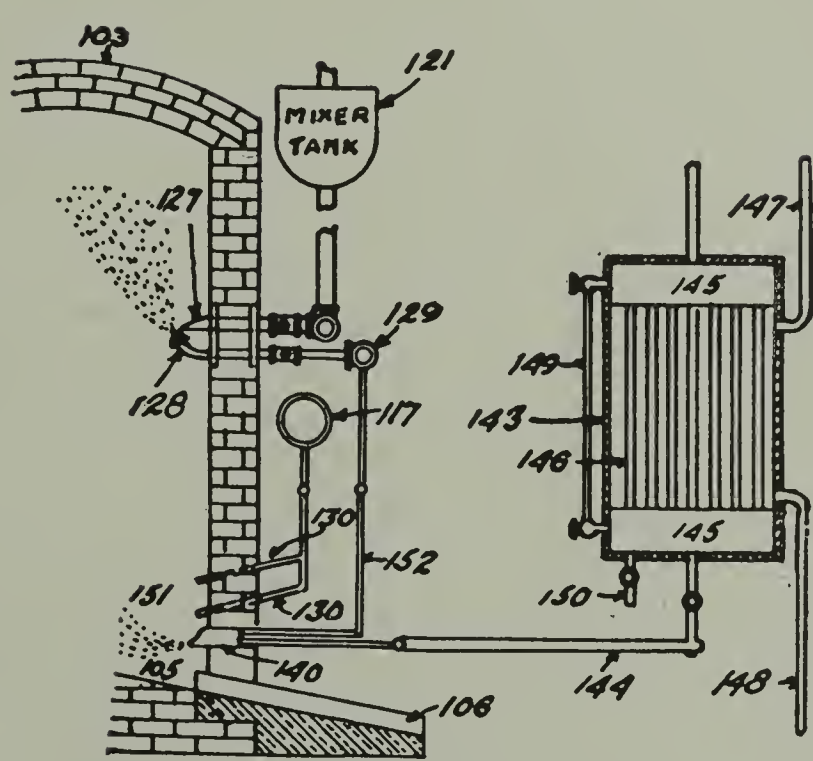


DIAGRAM 3.

third stage takes place of pump 21 and the fourth stage the place of pump 12. But it is shown as above for clearness.

Coil 14 is a spiral coil and may be enclosed in a tank as shown or in another spiral coil. Parenthetically I will state that the heat conductivity of a spiral coil per square foot per degree difference is greater than that of the straight pipe in the familiar double-pipe cooler for the same velocities. But this is a subject I cannot go into here, but I may in the near future devote a paper to this subject.

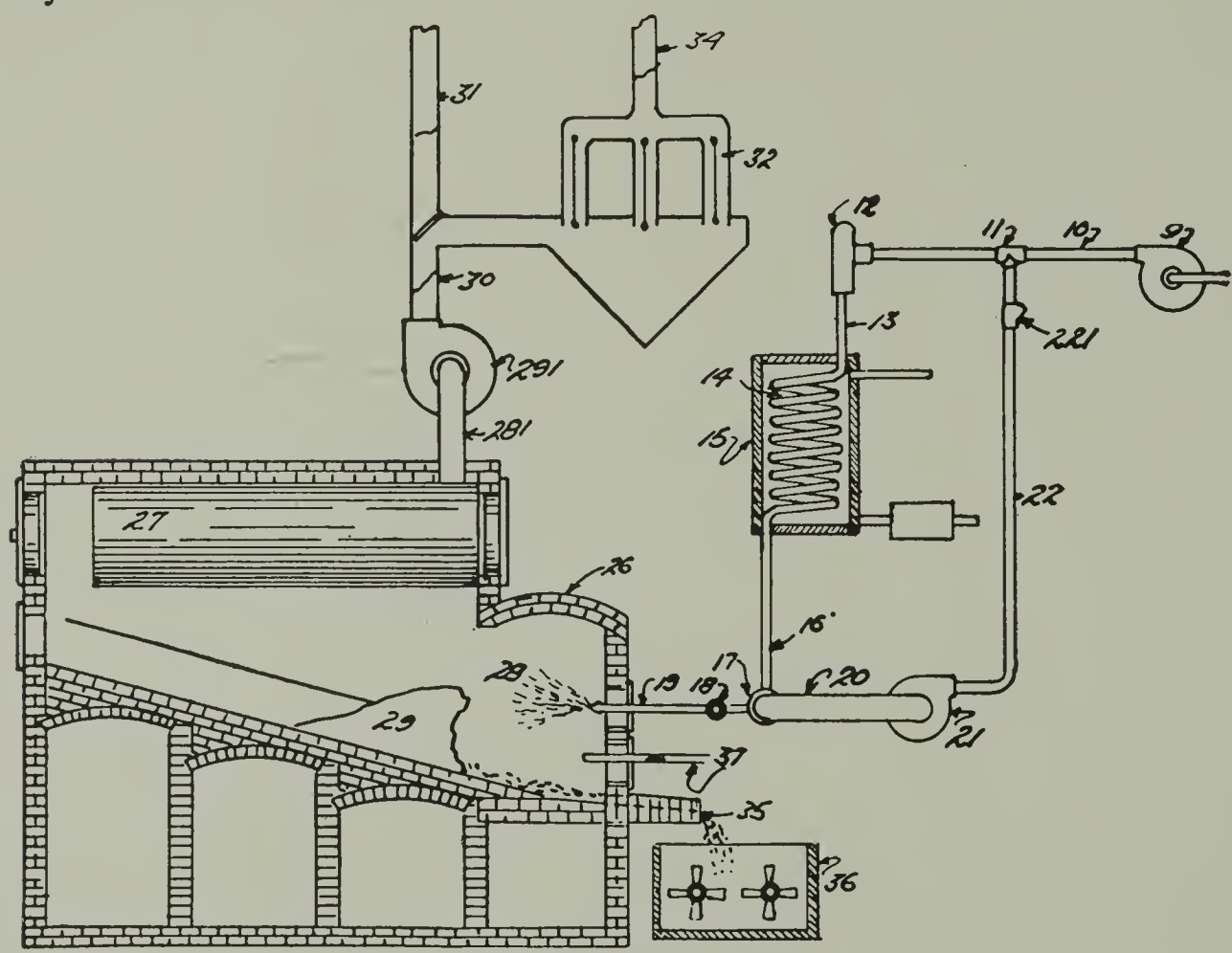


Diagram 4.

In the tank or surrounding coil is the heating medium, steam is suitable for temperatures up to 330° F. and hot oil for the higher temperatures. The air for combustion enters pipe 37 at from 2 to 5 lbs. pressure and digs into pile 29, which we endeavor to accumulate. The gases go under boiler 27, which serves the purpose of condensing the hot alkali and recovering heat from the hot gases. The gases then pass to the precipitator 33 which removes those particles still held in suspension. It is the intention that pile 29 shall slump forward, thus letting the molten alkali liquor run through the char on its way to spout 35 and dissolving tank 36.

The reduction of sodium phosphate to sodium sulphide is an endothermic reaction. The extra heat required for it is radiated from above to the char and thence conducted to the molten liquor running therethrough. Now it will be seen from the foregoing that the hotter the liquor is heated in the heater the less water has

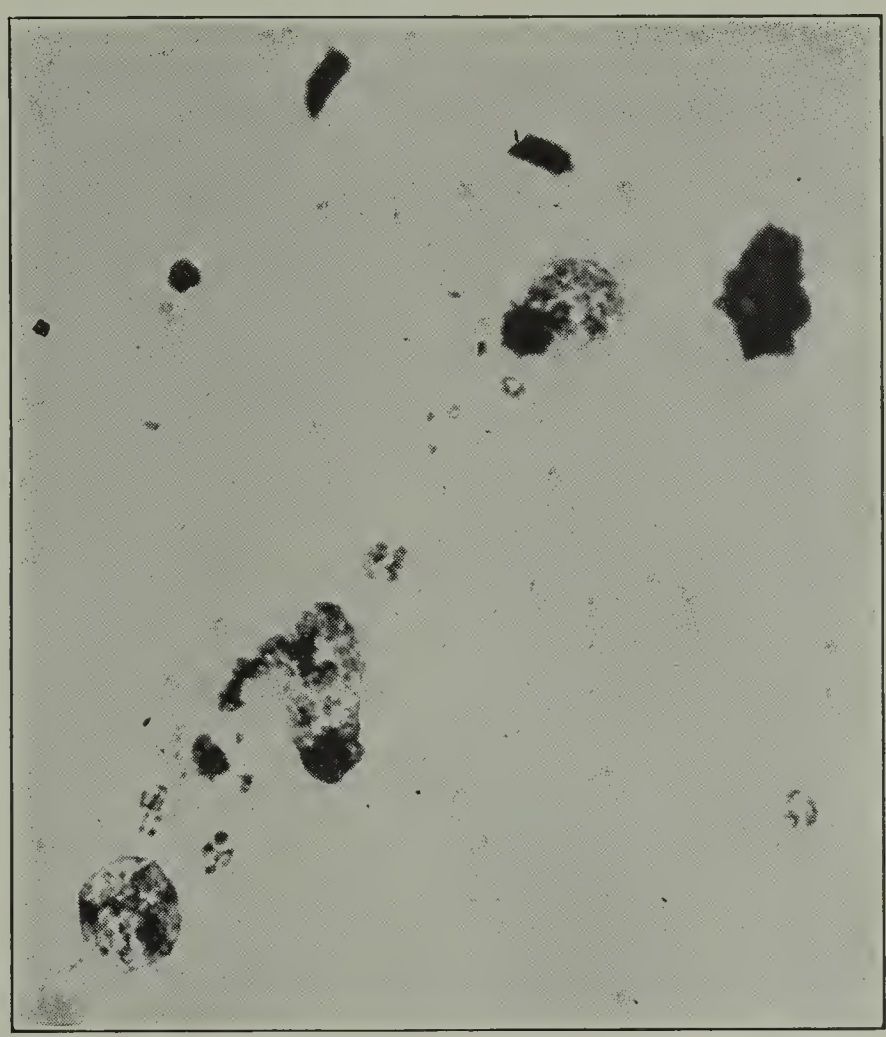


PHOTO NO. 1.—Magnification 400 dia.

to be evaporated in the furnace and the greater the explosion effect.

Now let us see what the results of this explosion gives us in actual practice.

We first tried to find the sizes of the particles of black liquor resulting from explosion. We passed several slides through the atomized liquor and examined them under the microscope. The results are illuminating as showing the effect of the explosion. The results here, Photograph No. 1, shows an average field of black liquor specks. This at a magnification of 10 does not show the smaller specks. This photograph was taken from black liquor exploded into the atmosphere at about 70° F. It is an indication

only for these were taken from liquor atomized into the cold atmosphere and in all probability represents only a small portion of the disruption which takes place in a hot furnace. Taking an average field we find the sizes of particles range in diameter from .032 mm. to 2.16 mm., and with thickness from .00447 mm. to .094 mm. Table XI shows the sizes of black liquor particles obtained by exploding the black liquor into the atmosphere. This was done with an explosion ration of 76, which is very low indeed.

TABLE XI.

DIAMETER AND THICKNESS OF BLACK LIQUOR SPECKS. EXPLOSIVE RATIO 76 EXPLODED INTO ATMOSPHERE

Diameter, mm.	Thickness, mm.	Diameter, mm.	Thickness, mm.	Diameter, mm.	Thickness, mm.
.0320	.00447	.127	.01340	.40	.0242
.0360	.00447	.161	.02390	.55	.0224
.0425	.00596	.187	.01640	.552	.1895
.0510	.01192	.212	.02990	.67	.0448
.0650	.01043	.229	.01640	1.04	.0717
.0650	.00894	.229	.02043	1.83	.0940
.085	.01043	.237	.01490	1.97	.0895
.119	.01340	.289	.02690	2.16	.0926
.119	.02043	.333	.02420		

From the above it will be seen that the thicknesses vary to a considerable extent even with the same diameters. In order to get at the number and sizes of specks in a given field a photograph was taken in which 1 mm. was represented as 3.5 centimeters.

The sizes were classified as follows:

Size *a* nearer to .037 mm. diameter than to other sizes
Size *b* nearer to .077 mm. diameter than to other sizes
Size *c* nearer to .118 mm. diameter than to other sizes
Size *d* nearer to .143 mm. diameter than to other sizes
Size *e* nearer to .233 mm. diameter than to other sizes
Size *f* nearer to .333 mm. diameter than to other sizes
Size *g* nearer to .400 mm. diameter than to other sizes

and circles in different-colored inks were drawn about each speck on the photograph according to which class the observer placed it in.

Table XII shows an analysis of one of these fields. This table

TABLE XII

124,500,000 SPECKS. 27.8 SQ. FT. ON THIS BASIS. SP. GR. DRY BLACK LIQUOR 20.29

Diameter, Volume, Surface of Black Liquor Particles at La Tuque in mm. or milligrams

Flat Diameter, mm.	Flat Thickness, mm.	Weight of Each, mgms.	Volume of Each mm.	Diameter if Spherical, mm.	Surface of Sphere.	Particles of Average Field.	Total Weight of Particles in Field, mgms.	Total Surface of Particular Field, mm.
a..... .037	.00447	$.1041 \times 10^{-5}$	$.4806 \times 10^{-6}$	.02093	$.1377 \times 10^{-3}$	280	.00292	.3857
b..... .077	.0104	$.9931 \times 10^{-5}$	$.4842 \times 10^{-5}$	.04557	$.6524 \times 10^{-3}$	169	.01678	1.1040
c..... .118	.0169	$.3792 \times 10^{-4}$	$.1848 \times 10^{-4}$	.07068	$.1570 \times 10^{-2}$	94	.03565	1.4760
d..... .143	.0186	$.6127 \times 10^{-4}$	$.2986 \times 10^{-4}$	.08294	$.2161 \times 10^{-2}$	86	.05269	1.8591
e..... .233	.0184	$.1609 \times 10^{-3}$	$.7847 \times 10^{-4}$	.1145	$.4114 \times 10^{-2}$	89	.14320	3.6620
f..... .333	.0242	$.4322 \times 10^{-3}$	$.2107 \times 10^{-3}$	.1591	$.7949 \times 10^{-2}$	66	.28520	5.2460
g..... .400	.0242	$.6237 \times 10^{-3}$	$.3041 \times 10^{-3}$	.1798	.1015	27	.16850	2.7410
						811	.70494	16.4738

27.8 sq. ft. radiating surface of black liquor particles present at one time, viz., .32 second.

shows the flat diameter, the flat thickness, calculated weight in mgms, and volume in millimeters of sizes of speck given, diameter of sphere of equal volume in mm., surface of sphere in mm.^{2}, with the number of particles of each in an average field, total weight of particles in field and total surface in mm. Now if a furnace burns 1.13 cu. ft. of liquor a minute and if the volume

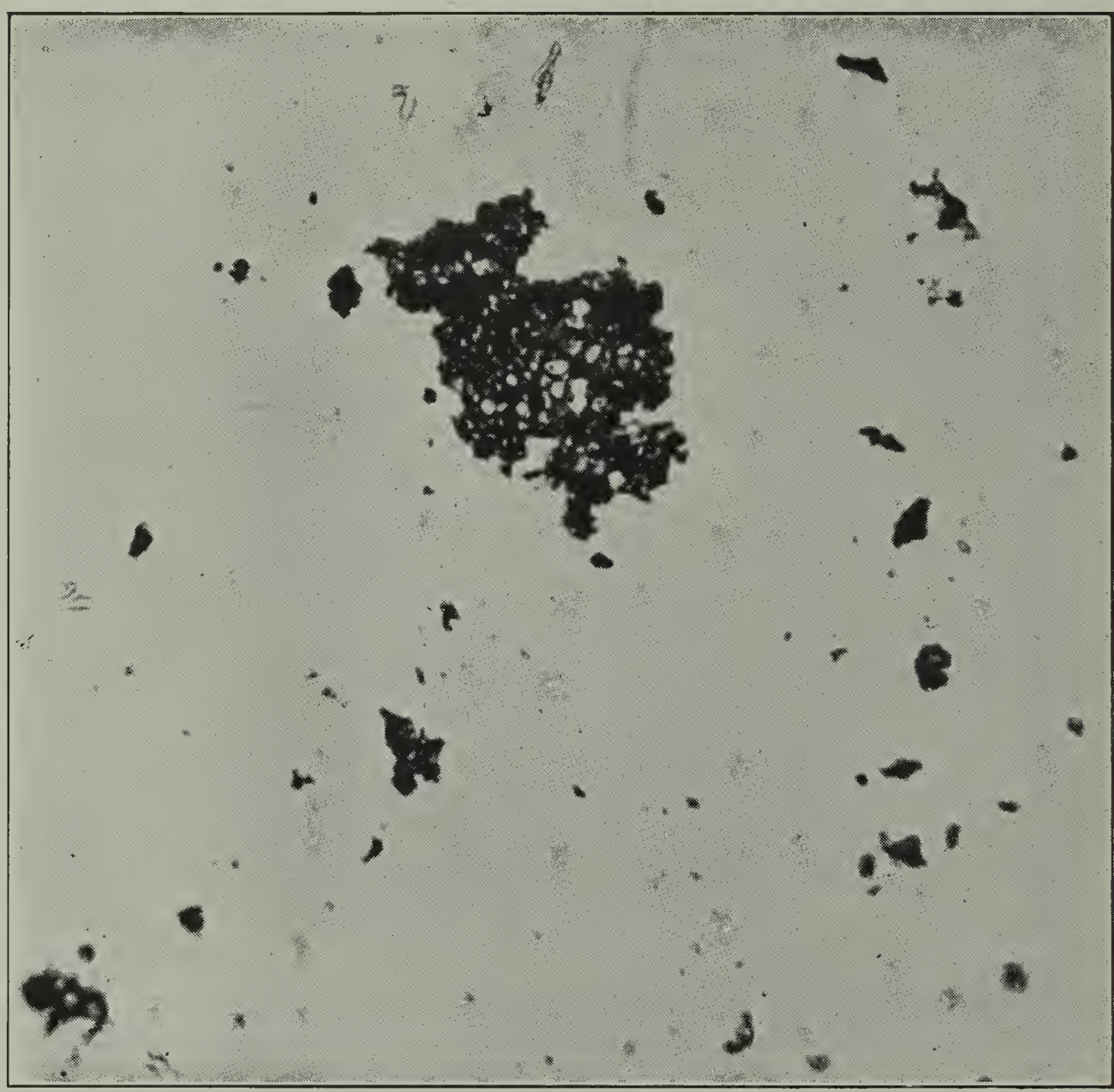


PHOTO No. 2.—Magnification 400 dia.

of the surface is changed every .32 second, then we can calculate the approximate number of specks, their total radiating surface and the amount of heat radiated from each. It might be of interest to know that this liquor atomized into the cold air would have specks in suspension in a space of 294 cu. ft. and have a surface of 27.8 sq. ft. If these particles were at 1950° F. they would radiate 56.4 B.T.U. in .32 of a second.

As the furnace has 273 sq. ft. of radiating surface it could of itself radiate 552 B.T.U. if the radiant rays could get to the flying spray, but as I look at this matter it is not only a question of having the radiating surface sufficient to radiate the required amount of heat, but the surface must be in such a position that the radiant rays are not intercepted by other bodies. The above is assuming that the temperature of the walls are 1950° F., and

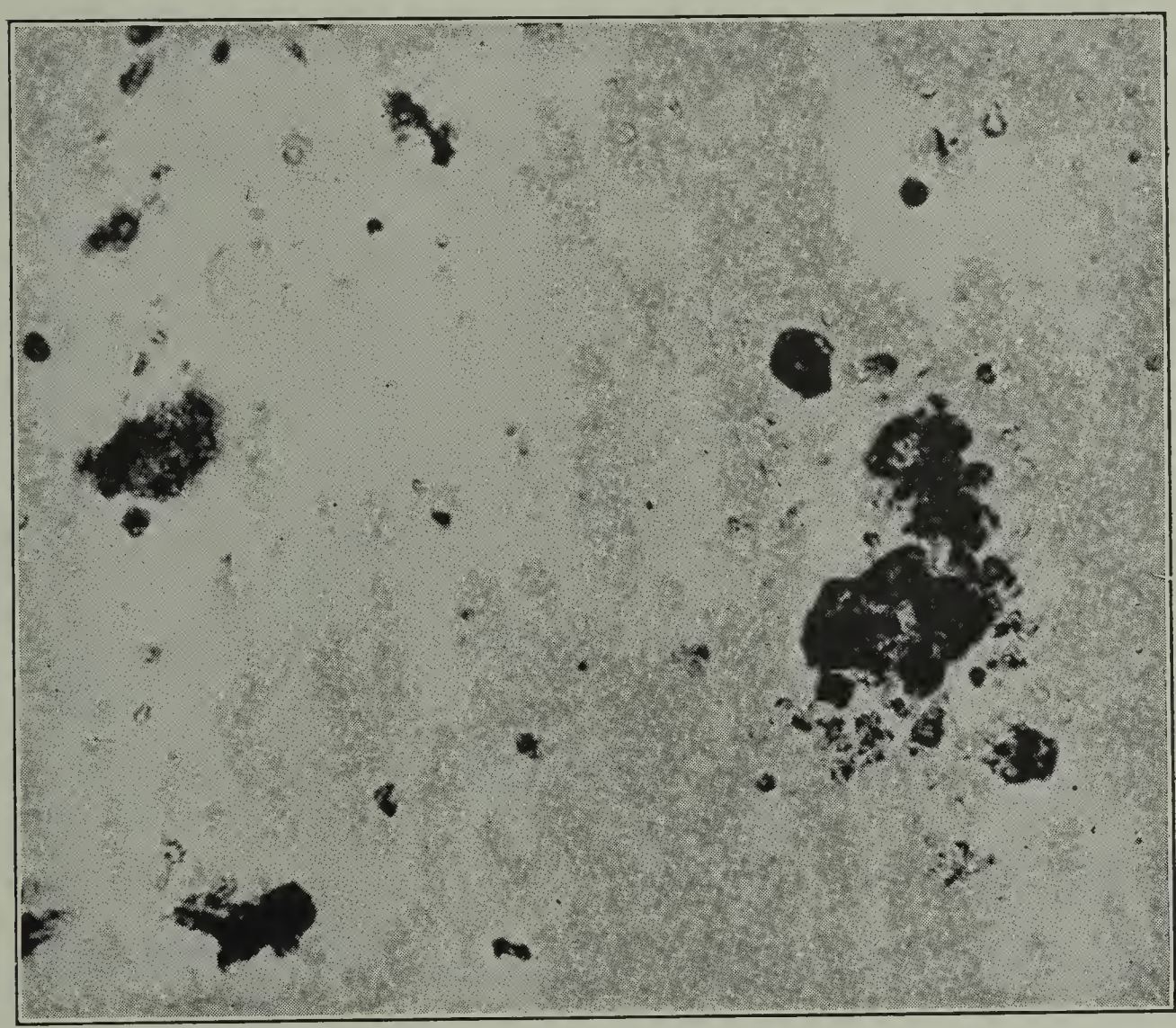


PHOTO No. 3.—Magnification 400 dia.

that the temperature of the black liquor particles was also at 1950° F. As a matter of fact we have reason to believe that the burning liquor particles have a temperature of from over 2000°, perhaps over 2150°, in which case they would have the power of radiating about twice as much heat as above given. As a matter of fact, the heat required for the evaporation of the water is only 19.7 B.T.U., so that we see that even at the lower temperature we have sufficient heating surface to effectually dry the incoming

liquor. As the smaller particles of this liquor take fire only a few inches from the nozzle we can imagine that we have them interspersed among larger particles which are constantly taking fire,

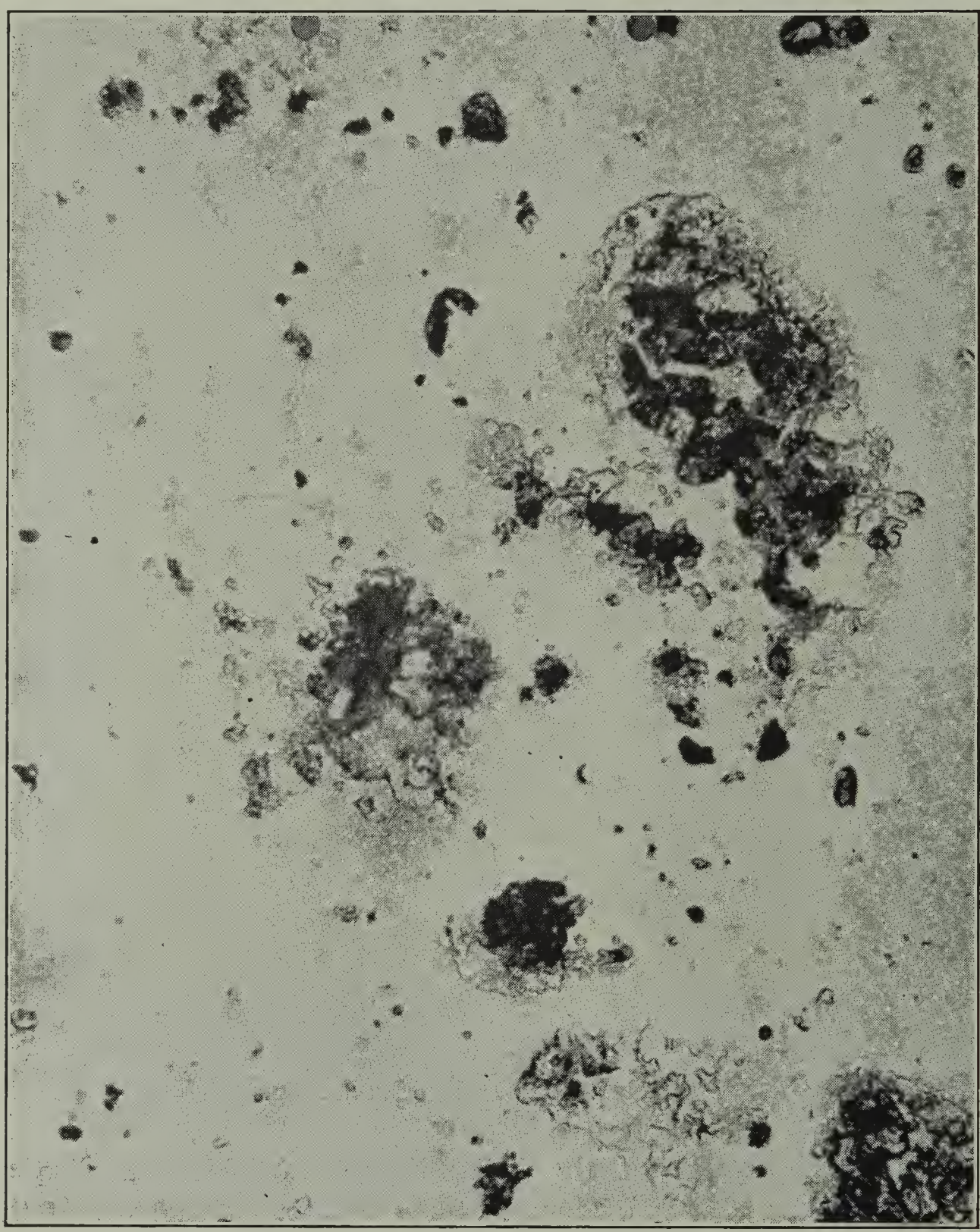


PHOTO No. 4.—Magnification 400 dia.

and that nearly all the surfaces are radiating effectively heat to other parts of the liquor. In this case we do not have to consider the specific heat of the particles as it is evident that if they contain nearly all the total heat entering the furnace, they can readily

spare this small amount of heat without lowering the temperature below 1950° F., the temperature of the whole furnace. It may be argued that as they burn they become smaller and thus expose less radiating surface. This might be so but for the fact that they break up into smaller particles still, so that instead of presenting less radiating surface they present a greater radiating surface, so even though the mass is smaller, the temperature will be maintained above the temperature of the furnace as long as there is

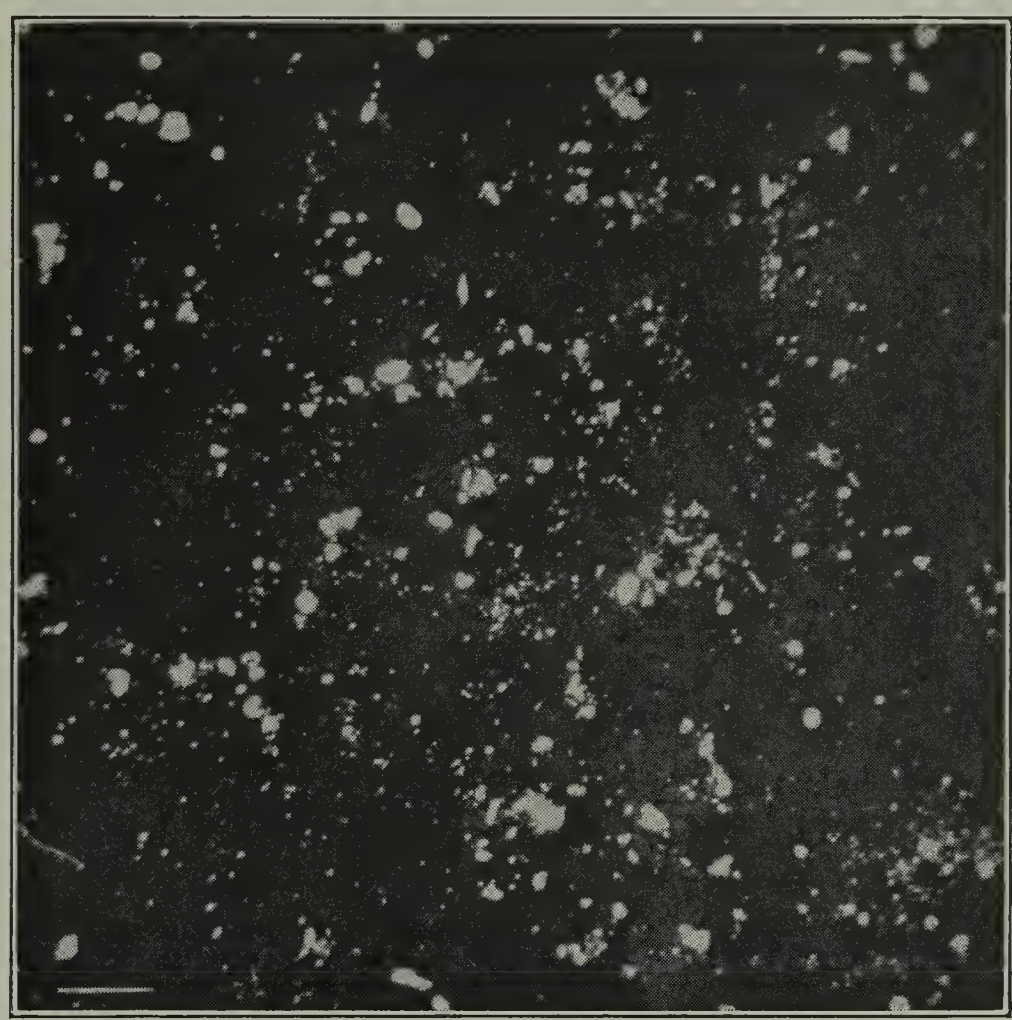


PHOTO No. 5.—Magnification 200 dia.

combustible material left in the ash. The particles cannot fall below 1950, as that is the temperature of the entire products of combustion.

It must be remembered that the liquor in practice is exploded into a furnace running at a temperature of 1950° or over, according to strength of the liquor, amount of preheat and composition of the products of combustion, etc. Now we have evidence that when this is exploded into the hot furnace the subdivision is much more complete.

In Photograph 2 is seen some of the smaller particles of black

liquor undergoing disruption. In Photograph 3 the honeycomb effect which precedes disruption is shown. In Photograph 4 and 5 are seen specks where partial combustion has taken place which was evidently checked on striking the cold slide. You will observe how disintegration has proceeded.

Now as this liquor burns up all but the very large particles while in transit of a distance of about 8 ft. we can assume that the ash of the liquor is in suspension in approximately the same

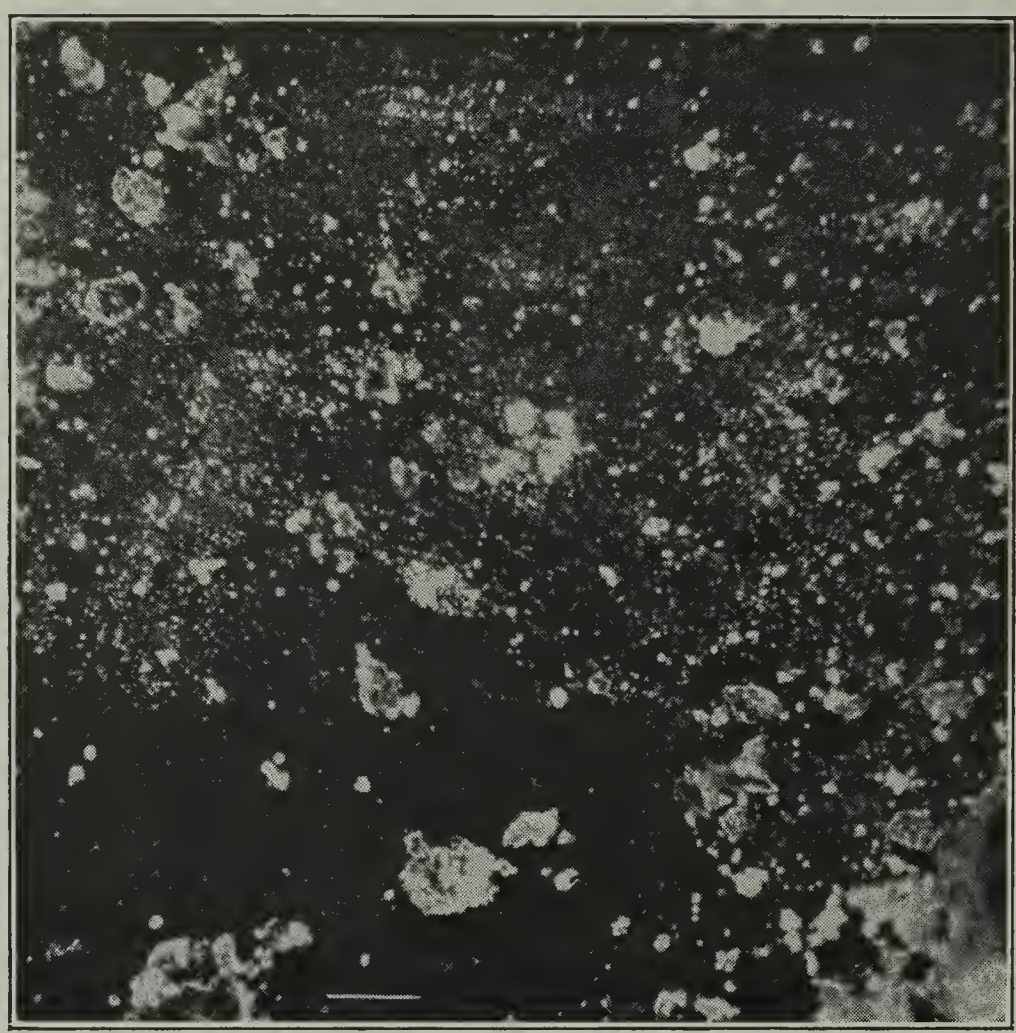


Photo No. 6.—Magnification 200 dia.

amount as it enters the furnace. With an object then of finding the number of specks present in the ash I took some slides from the gases coming from the flue and also from the vibrating puffs at the front of the furnace.

These specks were photgraphed and counted in the same manner as heretofore described.

Photograph 6 shows an average field of specks in front of the furnace and Photograph 7 shows an average field in the flue at back of furnace on the way to the precipitator. It will be noticed

that there are some particles in Photograph 7 which are larger than any of those in Photograph 6. The reason for this is that owing to the inertia of the large particles they were carried into a zone so far removed from the front of the furnace that they were not belched forth from the front of the furnace, but were carried by the flue gases and so show upon the slide at the back of the furnace. On the other hand it will be seen in Photograph 6

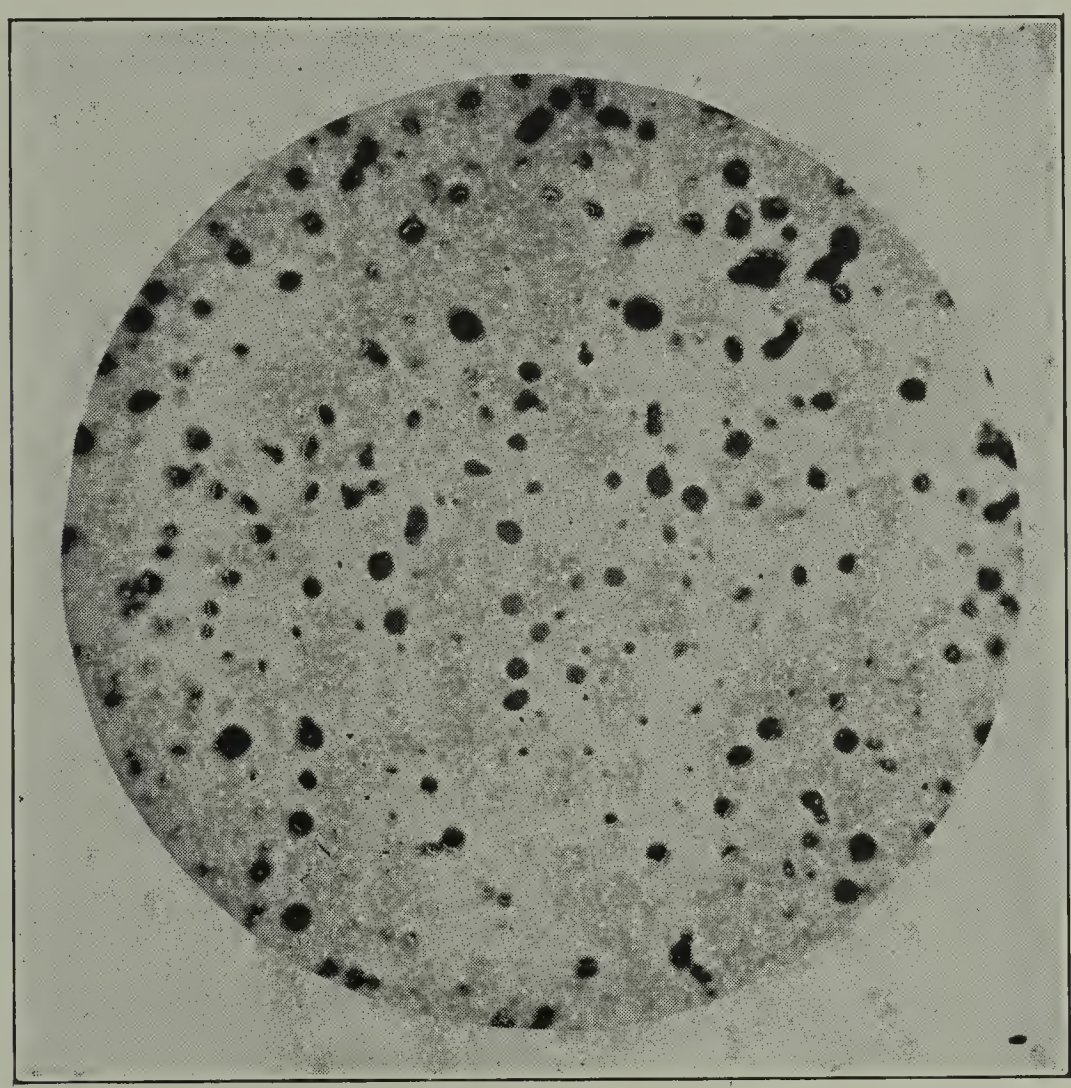


PHOTO No. 7.—Magnification 10 dia.

that there is not the large number of minute particles as in Photograph 7. In this latter photograph you can notice the characteristic milky way occasioned by a great number of small particles, too small to be outlined with a magnification of only 200. Compare numbers in Table XIV and XV.

Table XIII shows the average diameters and thickness of the specks in front of the furnace. The dimensions are in millimeters.

TABLE XIII.

DIAMETER AND THICKNESS OF SPECKS IN FRONT OF FURNACE

Diameter, mm.	Thickness, mm.	Diameter, mm.	Thickness, mm.	Diameter, mm.	Thickness, mm.
.0012	.00235	.00595	.00596	.01400	.00372
.0016	.00149	.00620	.003725	.01615	.01788
.0028	.00200	.00765	.00372	.01700	.00900
.0022	.00149	.00935	.003925	.01900	.00566
.0028	.00372	.00935	.002900	.02980	.02080
.0032	.002325	.00940	.00745	.03400	.02235
.0034	.00298	.0096	.00417	.03500	.01341
.0036	.00233	.01105	.01043	.05600	.03725
.0038	.00474	.0119	.01341	.07570	.00223
.0051	.00240	.0127	.00298		
.0054	.003725	.0134	.00298		

Table XIV shows diameter in mm., volume in mm.^{3}, surface in mm.^{2}, number of specks in a field and weight and total surface in an average field of specks taken in front of a furnace, and we find that if we figured the number of specks from this field that we should have 1,132,000,000,000 specks with a radiating surface of 319 sq. ft.

Table XV shows the diameter, volume, surface and weight of specks taken from the stock going to the precipitator. It will be noticed that those going to the precipitator have a much larger percentage of smaller particles.

If we figure all the ash in the particles of the size as coming from the back of the furnace we get 1,204,000,000,000 specks in the furnace at one time with a radiating surface of 332 sq. ft.

At the back of the furnace many of the particles have broken into smaller particles, but we have enough of the large particles such as we did not get in the front of the furnace still intact so that they materially affect the result by adding greatly to the weight of a few particles, and thus reducing the total number of particles, but not enough to counterbalance the increased surface due to the greater percentage of smaller particles.

It will be seen from the above that burning increases the radiating surface. After complete combustion we have no internal source of heat in these particles and in order to ascertain if they could then radiate the required amount of heat we should have

TABLE XIV

DIAMETER, VOLUME, SURFACE OF ASH PARTICLES TAKEN FROM LA TUQUE FURNACES (FRONT)

319 *sq. ft.* *Sp. Gr. of ash* 2.21. *Liq.* 28.4 *per cent ash.* (*Front of Furnace*)

Flat Diameter, mm.	Flat Thickness, mm.	Weight of Each, mgms.	Volume of Each, mm.^{3}	Diameter of Sphere, mm.	Surface Sphere, mm.^{2}	Particles in Each Average Field.	Total Weight of Particles in Field, mgms.	Total Surface of Particular Field, mm.^{2}
a... .0020	.00149	$.1035\times10^{-8}$	$.4680\times10^{-8}$	$.2075\times10^{-3}$	$.1353\times10^{-5}$	1072	.00001109	.014510
b... .0031	.00233	$.3886\times10^{-8}$	$.1758\times10^{-8}$	$.3226\times10^{-3}$	$.3270\times10^{-5}$	234	.00000209	.007650
c... .0050	.00306	$.1327\times10^{-7}$	$.6008\times10^{-7}$	$.4860\times10^{-3}$	$.7418\times10^{-5}$	130	.00001726	.009642
d... .0071	.00372	$.3254\times10^{-7}$	$.1472\times10^{-7}$	$.6552\times10^{-3}$	$.1349\times10^{-4}$	48	.00001562	.006473
e... .0100	.00774	$.1344\times10^{-6}$	$.6078\times10^{-6}$	$.1051\times10^{-2}$	$.3469\times10^{-4}$	33	.00004433	.011450
						1517	.00009039	.039725

1,132,000,000,000 specks.

TABLE XV

Diameter, Volume, Surface, Weight of Ash Particles, La Tuque Furnace

817,400,000,000. 332 *sq. ft.* *Sp. Gr. ash* 2.21.

Flat Diameter, mm.	Flat Thickness, mm.	Weight Each, mgms.	Volume Per Cent Each, mm.^{3}	Diameter of Sphere, mm.	Surface of Sphere.	Particles of Each Average, Field.	Total Weight of Particles in Field, mgms.	Total Surface of Particles in Field, mm.;
a... .0020	.00149	$.1035\times10^{-8}$	$.4680\times10^{-9}$	$.2075\times10^{-3}$	$.1353\times10^{-5}$	3531	.00003653	.04777
b... .0031	.00233	$.3886\times10^{-8}$	$.1758\times10^{-8}$	$.3226\times10^{-3}$	$.3270\times10^{-5}$	335	.00001302	.01095
c... .0050	.00306	$.1327\times10^{-7}$	$.6008\times10^{-8}$	$.4860\times10^{-3}$	$.7418\times10^{-5}$	209	.00002774	.01550
d... .0071	.00372	$.3254\times10^{-7}$	$.1472\times10^{-7}$	$.6552\times10^{-3}$	$.1349\times10^{-4}$	201	.00006540	.02774
e... .0100	.00774	$.1344\times10^{-6}$	$.6078\times10^{-7}$	$.1051\times10^{-2}$	$.3469\times10^{-4}$	66	.00008855	.02290
f... .0167	.00900	$.4356\times10^{-6}$	$.1971\times10^{-6}$	$.1555\times10^{-2}$	$.7602\times10^{-4}$	26	.00006224	.01976
						4368	.00029348	.14462

1,024,000,000,000 specks.

to consider their specific heat and find the total amount of heat in there at somewhere between 1950° F. and 2000° F., and see if they could spare the required heat, viz., 19.7 B.T.U. in .32 second.

If they received heat from no other source they would not have the required heat; they are now, however, so intimately distributed throughout all the furnace gases and they are receiving radiant energy from the walls and burning particles, so that they certainly can receive heat at the rate they are parting with it and so we need not trouble ourselves with this consideration.

From the above we may assume that, as the liquor is burning in transit, at its start it will have approximately 28 sq. ft. of heating surface as burning black liquor, while at the finish it will have no heating surface as black liquor, but approximately 320 sq. ft. in residual particles. On dividing each by 2 and adding, we should have approximately 174 sq. ft. of radiating surface in the flying particles. This surface, if kept at 1950° F., would radiate 827 B.T.U. to bodies at 211° F. in 0.32 of a second. The furnace walls at 1490° F. with 273 sq. ft. of heating surface theoretically have a power of radiating 552 B.T.U. in 0.32 of a second, but as they are the farthest distant from the flying particles their radiant waves are probably intercepted by flying particles so that the probability is that even though they have the heat they are very inefficient in being able to part with it to the incoming black liquor. They, however, do probably radiate some heat to some of the soda particles, which in turn radiate heat to the black liquor particles. What is true of the walls is probably true only to a lesser extent to the flying particles. These particles in burning are hotter than 1950° F., and radiate more heat than figured above. They are interspersed with the black liquor, so that a few may radiate heat from most of their surfaces, but many are able to radiate heat from only half of their surfaces and much of this heat is intercepted in its path to the black liquor particles by other soda particles. A much greater per cent of the radiant heat from these flying particles hits its mark, because the distance to the mark is measured in inches or fractions thereof instead of in feet, as is the case of the furnace walls, and the intervening particles must necessarily be proportionately less.

Referring again to Table IX we find that we have a considerable quantity of heat in the hot gases which can be recovered in a boiler. If we assume the temperature of the gases leaving the boiler to be 580° F. we have

Superheat in .604 lb. steam at 580	164
Heat in 1.923 lbs. N_2 + .1046 lb. CO	676
Heat in .089 lb. O_2	11
Total	851

or a total of 851 B.T.U. is going off in gases from boiler flues. Subtracting this from 2105 heat—these gases heat at 1950° F.—we have 1254 B.T.U. for every pound of black liquor which is blown into the furnace available for steam. From this, however, we have to subtract heat lost by radiation.

An actual boiler test shows that this is not very far from correct. The temperature of the flue gases was a little lower than those above given, viz., 495° F., and of black liquor burned for one hour was 34,000 lbs. The temperature of the feed water was 135° F., and the steam evaporated per hour at 115 lbs. pressure was 28,000 lbs., so that the boiler horse-power was 1050 and the heat absorbed by the boiler per pound black liquor burned was 900 B.T.U. This difference is probably due to radiation.

It will be seen from the above that the explosion process makes not only a good process for the recovery of alkali, which is of course the main object, but that it nets a substantial quantity of heat in available form to aid in reducing the coal bills. A few who have been privileged to see this process in operation have asked what effect gases containing so much sulphur have on the boilers. In reply I will say that we started these boilers in 1912 and have been operating them continually since that time. The processes have been improved, but the composition of the gases has not undergone any such marked change as to make the effect on the boiler noticeable. The boiler, however, has an entirely different function than to receive the heat from the hot gases by making steam. Each boiler is not only an evaporator, but it is also a condenser. If you will refer to the diagrams you will note that the bottom of the furnace underneath the boiler slopes continually toward the front in order to let the liquor condensed on and falling from the boiler run toward the front of the furnace.

When we first started these processes the furnaces were not built that way but were of the ordinary type of boiler setting. See Diagram 5. Now sulphide, sulphate, and carbonate of soda will sublime at the temperatures given and condense on the bottom of

the boiler, and it is the red-hot smelted alkali that I refer to when I mention liquor in a few lines above. Now if this sloping bottom is not so arranged as to let the liquor run forward you will have an accumulation of molten alkali behind the bridge wall which will run out of the clean-out door on to your blow-off pipes. This is not a theoretical consideration, but a factor of great importance. I have seen streams of molten liquor run from the clean-out door as big as my arm. Even now once a week an accumulation of several tons has to be cleaned out.

An analysis of the above will show that the efficiency is remarkably good.

Very few coal boilers average 15 per cent CO_2, in the gas with

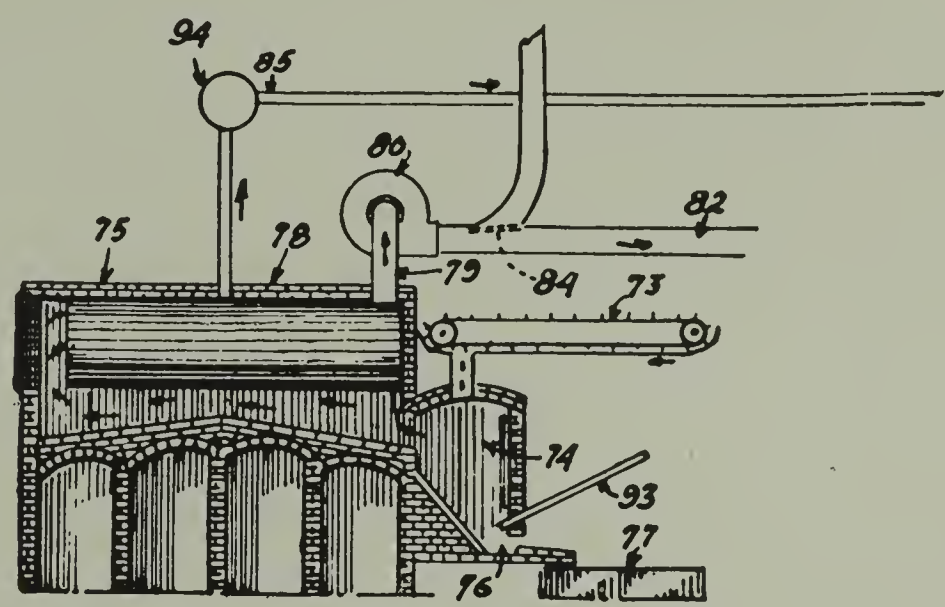


Diagram 5.

only 3.3 per cent O + .6 CO. Of course the CO is high, but it must be remembered that this is primarily a smelting reducing operation and that the recovery of heat is of secondary importance, and that it is necessary to have a reducing zone in the bottom of the furnace. This is formed by the accumulation of black liquor slumping forward and as this is so rich in carbon it reduces the Na_2SO_4 running through it to the excess heat for such reaction being radiated to it from above. (Note the excess nitrogen is due to burning the excess hydrogen in the liquor and thus removing the oxygen.) There may be a small chance of improvement by cutting down somewhat the excess of oxygen, but by doing so we might lose more heat in CO than we save.

Heating the incoming liquor to a greater extent will not make any more B.T.U. per pound of steam available, but it will increase

the capacity of the furnace so that less will be lost by radiation. There also are liable to be operating advantages. Increased heating the black liquor increases the explosive ratio and the increased subdivision of the particles, but this will also necessitate a precipitator always in perfect condition.

By increasing the subdivisions of the particles the chances of their receiving heat faster while in the black liquor state are increased, first, because there are more particles on fire; second, because those particles not on fire are more intimately distributed among the burning particles and consequently owing to their proximity will receive more of the heat which would be otherwise intercepted; third, the finer the particles are the greater the proportional amount of heat they receive from the surrounding atmosphere of hot gases.

A more complete reduction is obtained than the above, but this paper was started June 7th from data obtained much earlier. As far as the object of this paper goes, this does not matter, as the main object in view is to show the principles involved in a new recovery process rather than to give specific details of one operation.

DISCUSSION.

Dr. Moore: I might say that before building this plant we ascertained as far as possible what were the most approved practices in construction and operation of a sulphate mill. We had even sent a representative abroad to make recommendations based on personal observation. To put in a plant which was to be the largest and most up-to-date plant in the world in this part of Canada, necessarily involved the expenditure of great sums of money. While we could put up a new and up-to-date plant, we could not get anything but the most ignorant and slothful labor and consequently we could not make it pay anywhere near the operating costs, to say nothing of other costs.

This method of soda recovery was only one step toward putting this plant into very good position financially and I don't think there is any question but that this plant is the most economical sulphate mill in operation in the country to-day. Not only that, but we have the reputation of making the finest products in the country.

Neils Pederson came over to this country to buy some supplies for use in Europe and he had a bad case of the blues. He stated

that the cost of lumber and labor was as high in Europe as in this country, but bad as that was it was not the worst feature of the present conditions. He stated that the Brown Company was making a product equal to if not superior to any in Europe and so he could see no prospect of Europe recovering its American trade in these products.

The SECRETARY: Are you going to take us through that La Tuque plant next summer?

Dr. MOORE: Mr. Brown has never taken anybody through it but, owing to the ethics of the Chemical Engineers, which the other societies do not have, Mr. Brown has consented to take the American Institute of Chemical Engineers through his mill next summer.

Dr. HOOKER: I was also intending to suggest that we have some opportunity for discussion by seeing not only this paper but other papers.

Mr. HOWARD: I would like to ask Mr. Moore if he has ever considered the application of this process to other lines of work than this particular problem, and if so, what sort of thing?

Dr. MOORE: Yes, I have considered this, for instance, in relation to potash, recovering potash, we will say, from feldspar. The great trouble with recovering potash from feldspar is the wastefulness of high heat. But having worked this out and being able to recover the heat in the boiler, the heat and the high temperatures can be radiated down and by having your mixture moving on a chain stoker and carrying your potash, and so forth, through your radiant heat you may be able to radiate heat down, and with the Cottrell process you may be able to economically recover any vaporized matter. In the ordinary process of recovering potash from feldspar the loss of heat is so great that it is not economical. In this case you can recover your heat and you will find that these alkalies will not have any effect on the boiler. I have also thought of using the same thing in phosphite acid contemplation. You can radiate your heat down to it and recover all your heat through the boilers. A process like this must be carried out where there is a large consumption of steam, but there are plenty of plants which are located where there are deposits of these sorts where most of them can keep their pie, and eat it, too.

Mr. HOWARD: I want to point out that possibly the same process could be used for a variety of things which have no liquid fuel, and then they can use it over.

The PRESIDENT: You might conceivably mix powdered coal.

Mr. HOWARD: Yes, from suitable coal, powdered coal or pitch, or even fuel oil emulsifier.

Dr. MOORE: I don't think enough attention has been paid to this matter. As I showed you, with less than 100 degrees, the radiant heat being as the difference of the fourth powers, you get nearly twice as much B.T.U.—to illustrate, a body at 440° F. will radiate about 12 B.T.U. to a body at 211° F., while a body at 540° F. will radiate 21 B.T.U. to a body at 211° F. A body at 5500°, instead of 12 times as much, will radiate over 34,000 B.T.U. or nearly 3000 times as much. The efficiency goes up so tremendously fast that it is a thing which should be taken into consideration. It is going up as the fourth power, and the fourth power of a large number is a pretty important factor.

SOME DEVELOPMENTS IN CHEMICAL ENGINEERING

By A. E. MARSHALL

Read at the Savannah Meeting, Dec. 3, 1919

The war time demand for the products of the chemical industry has of necessity resulted in improvements in chemical engineering practice during the last three years. The inability of the factories in existence at the outbreak of the war to cope with war requirements was responsible for the erection, in this country and in England, of plants designed to produce large tonnage outputs of specific finished materials.

As the desired capacity was known in advance and as the product was definite, the designers of these plants had opportunities in arrangement of units which are lacking to a certain extent in the design of factories which have an indefinite future capacity and which necessarily will have to be extended at a later date to take care of new products and by-products.

An inspection of a number of the war time American factories, and six weeks spent in the English factories during the early summer of this year, has resulted in a conclusion that full advantage was not taken of routing of operations and of labor saving devices which in other industries had reached advanced states of development.

The imperative need for production and the necessity of adapting equipment available during the building of the plants has to be taken into account, and a full knowledge of the difficulties in securing prompt supplies of adequate machinery would doubtless modify in some measure conclusions based only on a study of the completed plants.

Even with such allowances, a survey of the latest developments of chemical engineering leaves a sufficient reason for the suggestion that the chemical engineer should broaden his lines of study from the limited one of the purely chemical field, to the wider viewpoint of engineering work and operation, in other industries which present problems analogous to the manufacture of chemicals.

The chemical engineer, or the chemical plant executive, is prone to believe that his manufacturing problems are peculiar not only to the chemical industry but even to his specific branch of the industry, whereas other industries have had similar problems and have reached solutions of these problems which are capable of adaptation to the needs of the chemical factory.

In the past, the average chemical plant has started out as a producer of one or of several standard chemical products, and with the development of the business, new but usually inter-related products have been added to the factory output. Invariably the original design was a complete unit so that even an increase in the output of the original products necessitated the addition of separate complete units without the possibility of effecting economies through the use of labor-saving devices applicable only to tonnage movements. When extensions through the multiplication of products became necessary the situation was much worse, as the new additions had to be located externally to the original plant unit, and the conveyance of materials produced in the original plant to the new units in which they were to be utilized was necessarily reduced to primitive forms of transportation. There are few industries to-day other than chemical manufacture which present the anachronism of linking up the travel of the semi-finished product of one operation to its final point of utilization, by manual means.

A generalization of this nature must of course be qualified by exceptions in the case of plants designed to produce large tonnages of the low-priced chemical staples, or as they are more generally termed "Heavy Chemicals." Such factories invariably have labor-saving tonnage movement devices, although they are not always in the forward state of development of the means used in other industries.

This difference is chemical factories is clearly evident in comparing the facilities for moving raw and finished materials in say a modern large tonnage ammonia-soda plant, and a plant producing six or eight products by stages. The soda plant will move its materials progressively with mechanisms which require the smallest amount of human labor, whereas the average several product factory makes each separate movement discontinuous instead of following the easily possible lines of regulated progression. Between the various inter-related units of a several-product chemical factory there is frequently a bottle-neck—of transportation of materials.

A study of what has been accomplished in the automobile industry in the way of linking up producing departments so that a constant output of finished automobiles is obtained, should open up to the chemical engineer a new vista of possibilities.

The South furnishes through its fertilizer industry excellent examples of discontinuous work.

A fertilizer plant can be as well ordered in its progressive stages of manufacture as an automobile plant, but the majority of the fertilizer factories move their entire output at least once and sometimes twice, during the stages of manufacture, by hand labor in buggies. Labor, in the South, was once cheap, and the incentive to the use of labor-saving devices and the proper layout and routing of departments was lacking. These conditions have changed with apparently no chance of return, and so the fertilizer manufacturer, and the chemical engineer specializing in fertilizer plant design, will be forced to build new plants in which economies in labor are possible.

This brings up the point of the original design of chemical plants and the necessity of designing with an eye to the future. Some chemical plants built within the last five years will find it difficult to make extensions which permit of a lowered cost of production or even a cost equal to the original plant, for reasons such as lack of strength in the building structure preventing the employment of mono-rail cranes or similar mechanisms to convey supplies of raw materials moving from the original storage bins or piles to the new extensions. Time can more profitably be spent in designing the present to suit the future than in trying to add in the future to a completed unit which has no outlets for expansion.

The statement made in the early part of this paper that other industries can furnish useful ideas to the designer and the operator of chemical plants is intended as a suggestion. To cover in detail the comparisons which present themselves would require several papers, so an attempt will be made to draw attention to some developments in other industries which are just finding their way into the chemical field or which are still awaiting proper recognition.

As a preliminary, there are some useful guide posts on the road along which the industry has passed.

Take the *Chemical Catalog,* which is issued under the auspices of this Institute, and compare the mechanical and labor-saving devices shown in the first volume (1916) with the much greater

variety in the present (1919) volume. The manufacturers are not listing plant equipment in 1919 that was not in existence in 1916, but rather they are listing equipment which in 1916 was used only in other industries. Compare also the advertising pages of the chemical journals say from 1912 to the present time, and note the introduction into chemical advertising, of filters which had found extensive use in the metallurgical field, of grinding machinery primarily developed for metallurgical plants and cement mills, belt conveyors, mono-rail cranes, grab buckets and other mechanical devices for handling materials which were introduced into chemical manufacturing processes after they had become standard parts for other industries. And to-day other industries have in use types of equipment which would solve many of the problems we consider solely as chemical engineering problems.

First there is the matter of moving materials through the cycle of the plant operation.

The movement, at the lowest possible cost, of large tonnages of raw and finished materials has assumed great importance in industries where there is close price competition. The progress of chemical manufacture with the consequent increase in size of chemical plants will make this feature of plant design of vital interest to the owners of these plants. Water-front factories bringing in their raw material by steamer will be forced to adopt unloading methods equivalent to those used in the iron and steel industry. Factories in the interior will have to be arranged so that railroad cars can be placed directly at the discharging or loading points so that double handling of materials is avoided. The linkage of materials, moving from one part of the plant to another, and referred to in the earlier part of this paper, will have to be changed from manual to mechanical means, and the plant units so arranged that the intervals to be bridged in the movement occupy the shortest possible distance while still permitting the future growth of the units.

All of these improvements in handling have become part of the routine design of other industries, and the chemical engineer, by extending his observation outside of the chemical field can usually find an operation, with characteristics similar to the project he is interested in, which has developed handling facilities adaptable to the needs of the chemical plant.

In the case of the chemical engineer concerned in the layout of a furnacing operation, a study of the modern central station power

plant will often suggest improvements over existing chemical practice. There are many chemical plants which use as much coal under furnaces each day as a large power plant does under its boilers. The power plant is in the business of utilizing coal for profit, so it has, in the movement of coal, displaced manual labor by mechanical methods. The power plant unloads its coal into storage with grab buckets operated from gantry or overhead cranes, and has developed other forms of mechanical equipment to convey the coal from storage to the boiler room and to the individual mechanical stokers. The ash from the boilers is gathered either by drag conveyors, pressure or suction devices and is delivered to hoppers which discharge direct into cars or ash scows.

The arrangement of the average chemical plant carrying on furnacing operations effectually prevents the use of a complete scheme of mechanically handling coal and ashes, as the furnaces have grown Topsy-like in various parts of the factory, and even the coal storage itself has usually to be placed remote from the furnaces.

The control of combustion, which is essentially a chemical problem, has progressed to a greater extent in power plants than in chemical factories, and it is the unusual chemical factory which has a complete equipment of CO_2 recorders, pyrometers, and draft-gauges on its furnaces.

Further suggestions along these same lines are afforded by the study of flow sheets of metallurgical works. The flow sheet of a modern smelter with its allied leaching and flotation plants represents a development in low cost movement far ahead of the average large chemical plant although the equipment used in the smelter is in many instances equally serviceable in chemical factories. Leaching by counter-current decantation in its present efficient state is a development due to metallurgical engineers who were faced with the problem of economically treating low-grade ores. The same apparatus will serve the chemical manufacturer for the production of solutions or an insoluble precipitate through the inter-action of a solid and a solvent or solution. The various types of classifier have made closed circuit grinding a possibility, and the chemical manufacturer can adopt from the metallurgist without change, a method of operation which gives a continuous finely ground product without a distinct intermediate separation.

Brief mention has already been made of filters used in metallurgical work and of their adoption in chemical processes. The

continuous removal of a solid product from a waste liquid or the continuous separation of a solution from a waste solid in suspension means a great reduction in cost as compared to the use of intermittent plate and frame presses.

The various processes of illuminating gas manufacture afford useful study, and some interesting developments should result from the adoption by the chemical industry of gas washers of the Feld type. Feld type washers have provided the gas engineer with a compact mechanism which gives an intimate contact between the gas and an absorbing or scrubbing liquid while the arrangement of the washer permits the liquid to reach a high concentration in solid particles without danger of stoppage. A cast iron washer of this type would, as an example, remove chlorine, using caustic soda solution as the liquid, from the exit of a chlorinating operation, and going for the moment outside the strictly chemical field, it might serve in an absorption method of recovering gasoline from natural gas, in place of the present expensive compressor plants.

Made of acid-proof materials, and somewhat modified in arrangement, this same type of washer might be used to replace one of the unsatisfactory details in a sulphuric acid chamber plant—the Gay-Lussac tower.

As an illustration of the satisfactory use of mechanisms developed in other industries, an instance at the factory with which the writer is connected, may be cited.

One portion of the plant operation depends on the continuous supply of large tonnages of raw materials. Prior to 1918 this raw material had always been delivered at the plant in steamers—and a complete scheme of mechanical unloading had been installed and had given excellent results.

The shipping strike and the shortage of steamers in 1918 made it necessary to change over from steamer to box car conveyance, and as the raw material was used at the rate of 600 tons a day it meant either excessive hand labor in unloading the cars or the adoption of some mechanical unloading device.

A review of practice in the chemical industry did not afford any suggestions, neither did the usual engineering catalogues or trade publications refer to a machine which would solve the problem.

Consideration of materials that were moved in tonnages in box cars led to an investigation of the grain industry, and it was found

that the grain elevators had been using a mechanical box car unloading device for at least 10 years and that this device could be adapted without change to the conditions we had to meet.

The grain unloaders were installed, and as a result of their use the movement of incoming raw material kept pace with the consumption. The congestion of plant facilities through the inevitable delays which would have occurred under hand unloading conditions were avoided, and most important of all, the cost of putting the material into the plant was kept down to a reasonable figure.

In bringing this paper to an end, the examples which have been selected do not exhaust the possibilities of comparison, but they will serve the writer's purpose if they are accepted as evidence in support of the conclusions which were advanced in the first paragraphs—that the chemical engineer can study to his advantage, engineering progress in other lines of industry.

DOUBLE PIPE HEAT INTERCHANGERS

By GEO. A. RICHTER

Read at the Savannah Meeting, Dec. 3, 1919

The chemical engineer is vitally interested in experimental data giving information on the flow of heat from one fluid to another through metal surfaces. Although many papers have been written on this subject, there is still room for a vast amount of experimental work to confirm established heat laws and to pry further into unknown regions.

Geo. A. Orrok gives an excellent review of published information on conductivity experiments in the 1910 volume of the Transactions of the American Society of Mechanical Engineers. Most of the work so summarized refers to the surface condensation of steam, and although some of the deductions listed may be applied directly to a liquid-to-liquid heat interchange, the conclusions reached must be studied with due reservation. A host of formulæ have been presented by experimenters for surface condensation. It is very probable that discrepancies in their results do not point necessarily to inaccuracy in work, but may give evidence that there are other factors involved which have not been recognized.

Although the experimental work upon which this present paper is based concerns only double pipe heat interchangers, using hot and cold liquids, a brief résumé of heat transference in general may not be out of place.

Definition of Conductivity

Heat transference is conventionally expressed in terms of heat units transferred per unit of surface per unit of time per unit difference in temperature. In this country English units are employed. A given system has a certain conductivity (K) representing the number of British thermal units transferred per square foot of surface per hour per degree difference in temperature between

the hot and cold fluid. Mathematically this temperature difference is the logarithmic mean of the incoming and outgoing hot and cold liquids:

$$T = \frac{D_1 - D_2}{\log_e \frac{D_1}{D_2}},$$

where D_1 represents the difference in temperature at the beginning of the system and D_2 the difference at the end.

It is at best exceedingly difficult and probably impossible to cover all cases of such heat transference by means of a few well-selected formulæ. A new condenser, or a surface heater of radically different design, always requires experimental investigation in order to learn more concerning the application of heat laws already in existence. Such investigation sometimes involves the fixing of new constants in equations already worked out for other types. Often it means the establishment of entirely new relationships.

Plant Considerations

The conductivity, or K, of a system is a function of the rate of heat transfer in that system. Often the value of K is all-important in the design of new cooling or heating installations. There are cases, however, where other factors are equally important. In general, the design of a new interchanger involves the following plant considerations:

1. Conductivity, or K, of various types of units.
2. Capacity of interchanger in total B.t.u. per volume of space occupied.
3. Amount of fluids to be pumped or moved in other ways.
4. Power required.
5. Limiting temperatures of incoming and outgoing fluids.
6. Construction and determining cost of material, practicability, resistance to corrosion, etc.
7. Intelligence required in operation.
8. Physical and chemical characteristics of fluid to be heated and cooled.

Each problem is apt to present other phases for consideration, depending upon requirements. Sometimes one factor of those

enumerated above is of paramount importance. Factors two to eight as listed demand the application of engineering sense and judgment. The conductivity factor cannot be calculated from theoretical principles and consequently most of the experimental work on cooling and heating systems is concerned with that end of the problem.

Effect of Velocity of Liquor

If the total cost of introducing or abstracting a given number of B.t.u. in a system is to be minimized, compensatory advantages and disadvantages must be carefully weighed. For instance, the engineer must decide whether it will pay him to raise the conductivity by increasing the velocity of the liquid. In order to make such a decision he must have experimental data showing the effect of liquor velocity on power consumption of pump as well as on conductivity realized. He knows in general that raising the velocity either of the hot or of the cold liquor will increase the conductivity. He also knows this increase in conductivity is not a straight line function of the power consumption involved. The above example is merely one of several which confront the engineer on any new cooling or heating installation. The more data available the less guesswork and worry results.

Several investigators have established equations showing the effect of velocity of liquor on conductivity. Their equations vary quite considerably. In general, they express conductivity as a function of the nth root of the velocity of liquor. This value n is usually different for different types of condensers, and consequently an equation cannot be taken without a thorough study of conditions under which this equation was established. Factors of which we have little knowledge may cause very great changes in conductivity with but slight changes in design.

Importance of Film Velocity

For example, we may state with some assurance that the so-called film velocity of water has marked effect on conductivity realized. But what determines film velocity? Results tabulated in a later part of this paper indicate rather forcibly that a very slight change in design of heat interchanger may cause an almost unbelievable change in conductivity, and there appears to be no better

explanation than that there has resulted a greater film velocity although the average velocity has not been altered. Marked differences in formulæ established in the past and in our own work emphasize the necessity of more intense study and further experimental investigation.

Scope of Investigation

As stated before, the work discussed in this paper concerns mainly the efficiency of so-called double pipe heat interchangers. We were interested in a system represented by a liquid-to-metal-to-liquid heat transfer. Inasmuch as the problem involved cooling acid liquors, a lead inner pipe was enclosed in a wrought iron jacket pipe. The procurement of maximum thermal conductivity was necessary in order to conserve lead pipe and to use a minimum amount of cooling water.

Although several designs of coolers were constructed for experimental data, this paper confines itself to a comparison of two types, the helical and the straight length. Sufficient data was accumulated to establish direct relationships, which may to a limited extent be used in considering other designs. It is to be noted, however, that although the factors which influence conductivity in these tests may be used qualitatively for other types of coolers, no quantitative relationship should be assumed.

Final Objects

Tests were carried out with three objects in view; first, to determine whether a double pipe coil put into the form of a helix would give higher conductivity than one with the same pipe dimensions put into 20-ft. lengths; second, to learn more regarding the effect of varying the diameters of the inner pipe of a helical cooler; third, to study the effect of changing the overall dimensions of a helical cooler.

Apparatus Used

The units were set up as follows:

1. A 60-ft. 1-inch lead pipe within a 2-inch wrought iron pipe arranged in three 20-ft. lengths. The general assembly and a cross section of the double pipe in shown in Fig. 1.

2. A 60-ft. 1-inch lead pipe within a 2-inch wrought iron pipe wound in the form of a helix and connected by flanges as illustrated in Fig. 2.
3. A 120-ft. 1½-inch lead pipe with a 4-inch wrought iron pipe flanged and wound in the form of a helix as shown in Fig. 3.
4. A 120-ft. 2-inch lead pipe within a 4-inch wrought iron pipe wound in the form of a helix in exactly the same way as represented by Fig. 3.

Each of these four coolers was set in place in very much the same way. The method for determining volume of liquor, temperatures, and velocities is shown diagrammatically by Fig. 4. Before each test, the hot liquor to be cooled was heated in a tank to the desired temperature by means of live steam. The volume delivered during the test was measured directly by drop of the level of the liquor in this tank. Cold water was pumped through the jacket and delivered over a weir for measurement. Pump pressures were regulated by means of a rheostat and thermometers installed at parts needed. Usually a series of runs were made with different initial temperatures, in order to determine whether the temperature difference of hot and cold liquor materially influences the conductivity. During the test, readings were taken of the volumes and temperatures of ingoing and outgoing liquor every thirty seconds. The first readings were recorded after the system had been operating one full minute, in order to allow time for equilibrium to be established. Knowing the cross-section of lead pipe and wrought iron pipe, the velocities could be calculated.

Variables Studied.

The following factors influencing the conductivity in each case were studied:

1. Velocity of cold jacket water.
2. Velocity of hot water within lead pipe.
3. Change in conductivity due to a change in temperature.
4. Pressure of hot and cold water entering the system.
5. Change in conductivity due to change in design of cooler.

The tabulated results and data obtained in this way are included in the appendix. The computed values are shown by charts.

Helical vs. Straight Length Cooler.

Chart I illustrates the change in conductivity of No. 1 and No. 2 coolers with change of velocity of hot water, the cold water velocity being held practically constant. Chart II pictures the change in conductivity taking place with different cold water velocities, keep-

Chart I.—Velocity of Hot Water in Feet per Second. Conductivity per Hour per Degree per Square Foot.

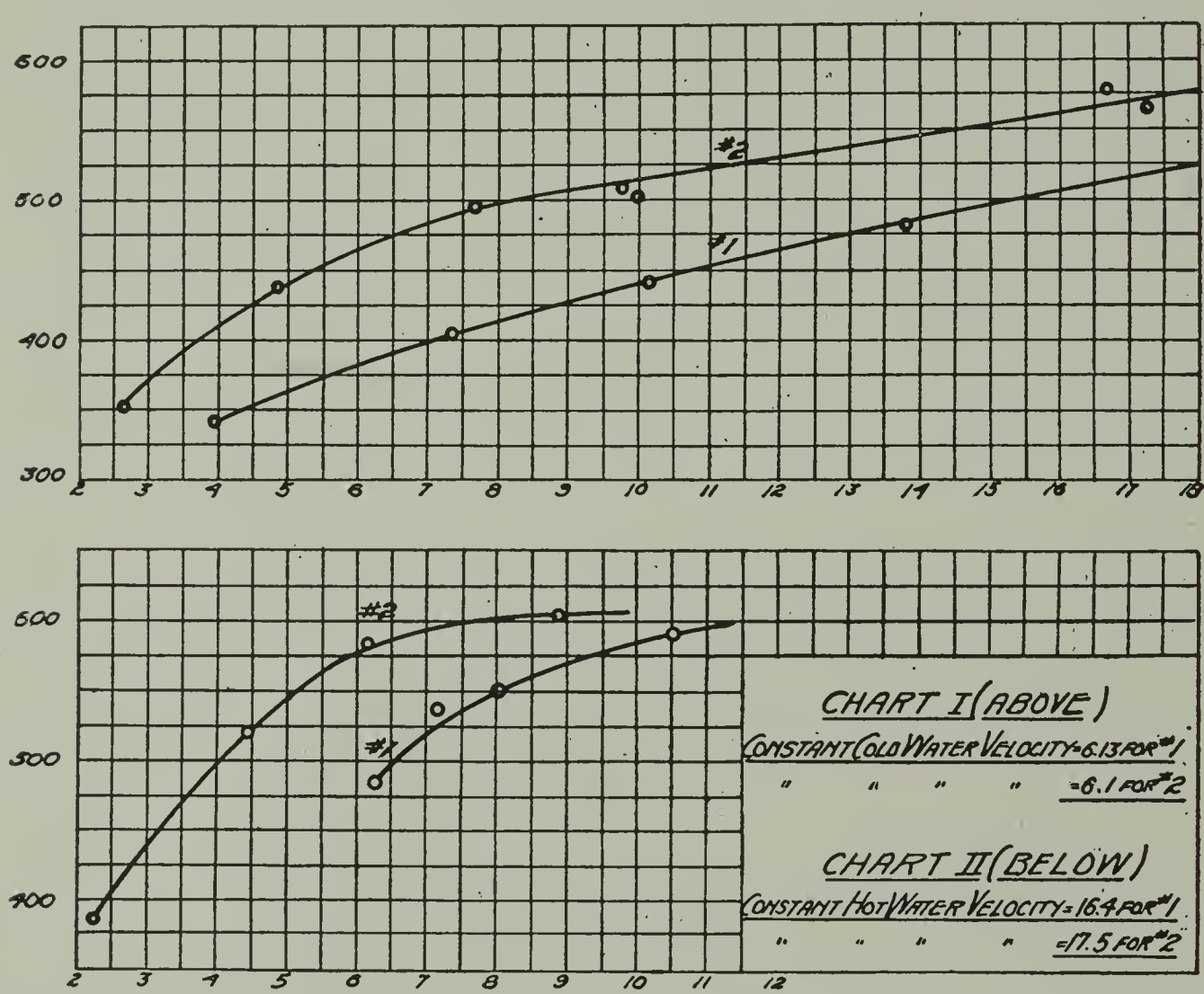


Chart II.—Velocity of Cold Water in Feet per Second. Conductivity per Hour per Degree per Square Foot.

ing the hot water velocities practically constant. Inasmuch as there is no change in pipe dimensions, the differences in K represent the effect of curvature in the pipe.

Both charts show a substantial increase in K as the velocities of liquids are increased. This was to be expected. At corresponding velocities, the helical cooler gave in each case a higher K, indicating that the pipe curvature does increase the effectiveness of heat transfer. Chart II represents runs made with a rather high

(17 ft. per sec.) velocity of hot water, and consequently the entire curve lies in a region higher than the curves shown in Chart I, which represents runs with a constant cold water velocity of only 6.1 ft. per sec. Moreover the curves in Chart II are steeper, showing a greater mathematical change in K with change in cold water velocity.

Molier calculated from Joule's researches (Zt. d. v. d. Ing. 1897, No. 6) that the conductivity of heat from liquid through copper to liquid could be represented by a formula—

(English Units).

$$K = \frac{61.5}{\frac{1}{1+3.3V_h^{.5}} + \frac{1}{1+3.3V_c^{.5}}}$$

where V_h and V_c represent velocity of hot and cold liquids respectively. Such an equation means that either hot or cold water velocity increments have equal effects in changing conductivity obtained. This is probably true for some forms of coolers, but is dependent upon the design.

Equations were deduced from the experimental data on cooler No. 1 and No. 2 and are put into similar form as taken by Molier's equation.*

Cooler No. 1 (straight pipe).

$$K = \frac{62.7}{\frac{1}{1+5V_h^{.57}} + \frac{1}{1+5V_c^{.57}}}. \quad . \quad . \quad . \quad . \quad . \quad (1)$$

Cooler No. 2 (small helix).

$$K = \frac{76.2}{\frac{1}{1+5V_h^{.60}} + \frac{1}{1+10V_c^{.50}}}. \quad . \quad . \quad . \quad . \quad . \quad (2)$$

It is to be noted from these formulæ that with each cooler an increase in cold water or jacket velocity can have a greater effect in increasing K than a corresponding increase in hot or inside water velocity. This may be due to a greater actual increase in film velocity of water in the jacket than that obtained by the same increase of average velocity of liquid within the inner coil, and this

* See Appendix for explanation.

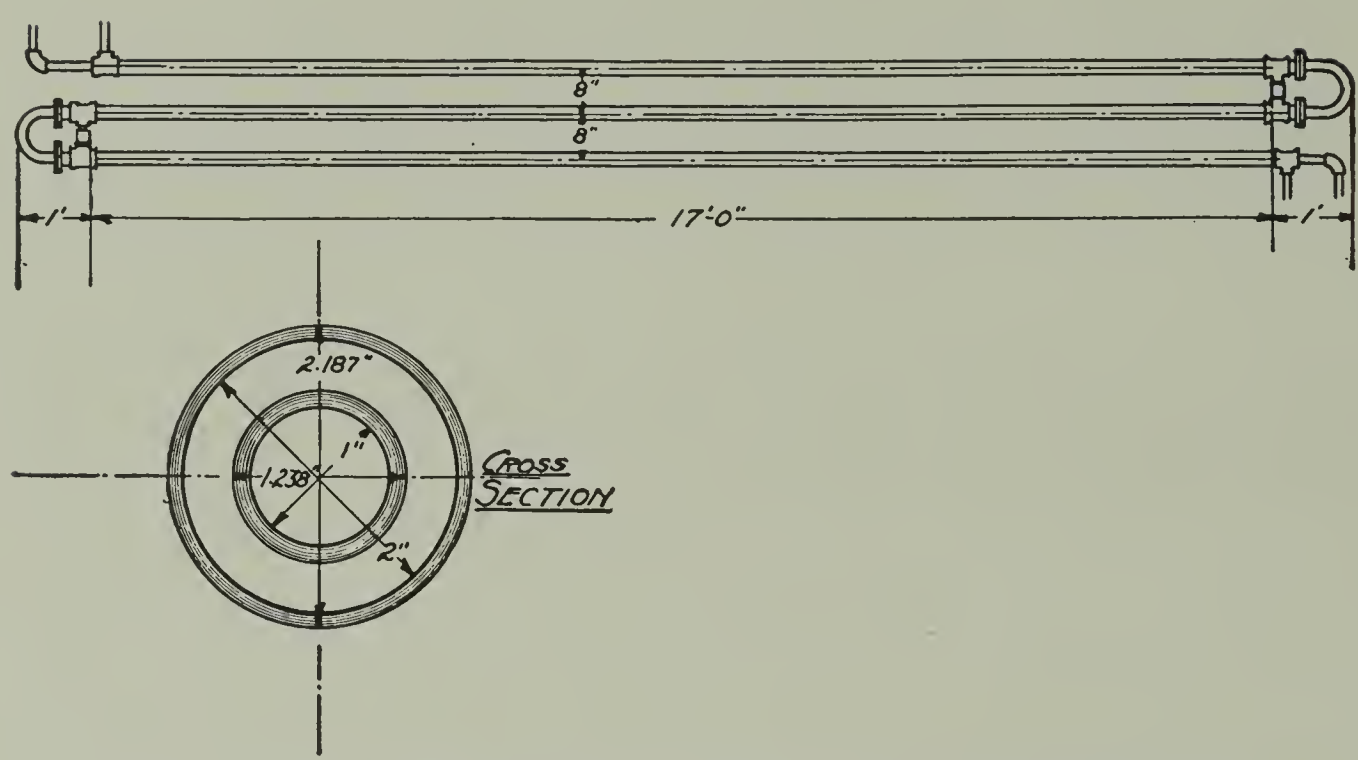


FIG. I.—Sketch Showing One View and Cross-section of Straight Cooler.

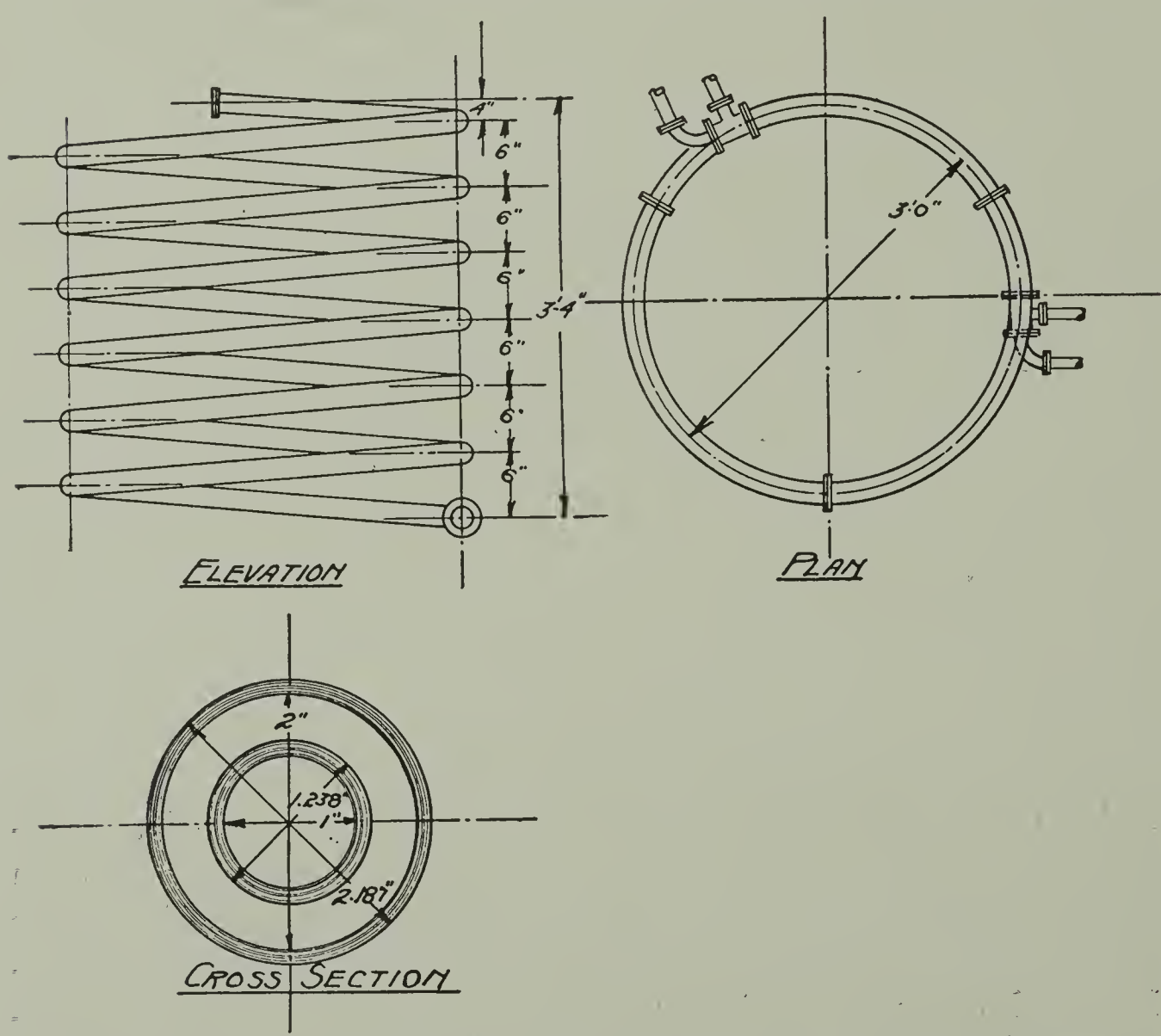


FIG. II.—Sketch Showing Two Views and Cross-section of Helical Coil. Cooler No. 2.

greater increment may be caused by the obstruction formed due to the position of the inner pipe. In order to get a clear mental picture of this explanation offered, it will be well to consider a sketch (Fig. V) drawn to represent and distinguish average velocity and film velocity in the same pipe or tube.

The diagram shows a cross section of a double pipe cooler, water flowing in the direction of the arrows. The average velocity in both jacket and in the coil is equal and represented by A.V. We have reason to believe that it is not this A.V. which determines the *K* of the system, but rather the film velocity, and this F.V. is evidently dependent upon the cross section of channel as well as the A.V. of

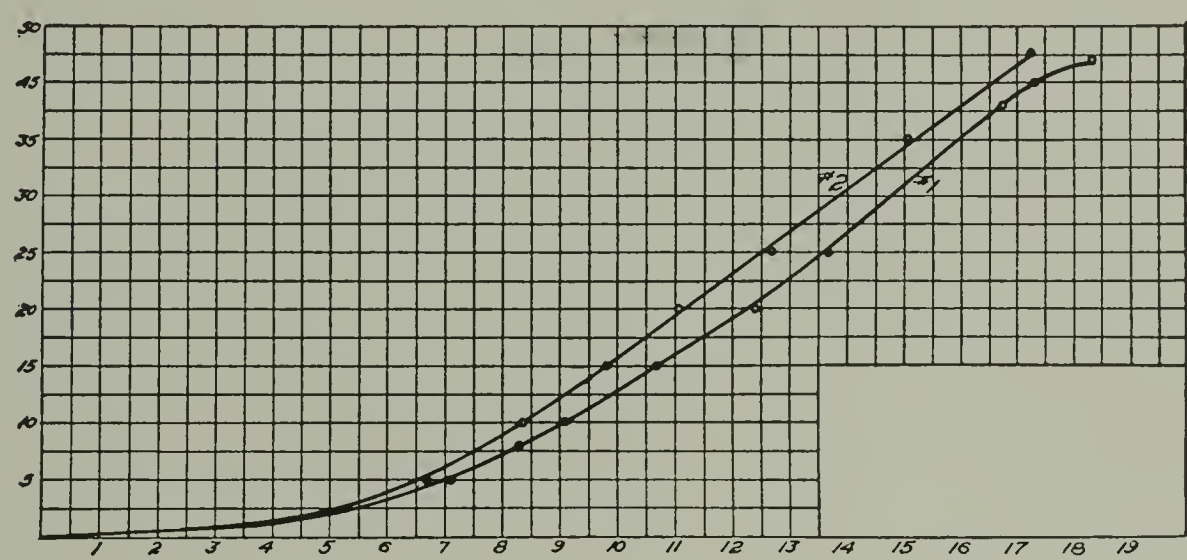


CHART VIII.—Veolcity in Feet per Second. Plot Showing Velocity in Inner Coils as Affected by Pump Pressure.

total liquid flowing through. Thus, we would state that the smaller the cross section of the pipe or other channel, the higher will be the actual film velocity for a given A.V. As inferred above, quadrupling the A.V. may increase the film velocity of the inner coil by two, whereas the same increase of average velocity in the jacket may raise the film velocity of the jacket water by 2.5. We do not know whether *K* is *directly* proportional to film velocity. If it is, then by reversing the computations used, one could actually calculate the effect of increased A.V. on increased F.V., or solve the equation:

$$\text{F.V.} = f(\text{A.V.})$$

In imagining the flow of water through a helical and through a straight cooler, it is not difficult to picture a higher F.V. for a given A.V. in the case of the helical cooler. The A.V. is calculated

from actual gallons delivered and does not take into account the path of each particle of water as it travels through the cooler. The helical form would naturally add rotary as well as linear motion and result in greater total velocity of water film next to the surface. The data plotted confirm such a prediction. The conductivities obtained with the helical form of cooler averaged from 10-20% higher than those obtained with the straight cooler.

The question of power arises. The rotary motion evidently causes more friction, and would necessitate a greater pump pressure to deliver a given capacity of water. Chart No. 8* shows the pump pressure plotted against average velocity with both coolers.

In the operating region of the chart the straight cooler shows a greater A.V. at a given pressure of about 1 ft. per sec. Referring back to Charts I and II it will be noted that it would require a 4-5 ft. difference to compensate for difference in K found.

There are other analogies and differences which may be pointed out in reviewing the data from which these curves were drawn, only one of which will be considered here. For many years experimenters have made attempts to find relationships of K and temperature difference in a given system. The curves as plotted in Charts I and II are based on data which include at least four runs at each point, the initial water temperature ranging from 110°-180° F. A careful survey of the data † indicates that in general the K goes up very slightly with the initial temperature of hot water. Inasmuch as the initial cold water temperature was held practically constant during any given series, an increase in initial hot water results in a greater average hot water and cold water temperature of both liquids passing through the apparatus. The only explanation we have to offer for a slight increase in K with higher average temperatures in the system depends on the fact that the viscosity of water decreases as the temperature is raised. It is probable that the film velocity for a given A.V. increases as the fluidity of the liquid increases, thus allowing greater conductivity. Graphically, we may represent in an exaggerated way the film velocity of water at three different temperatures. (Fig. VI.)

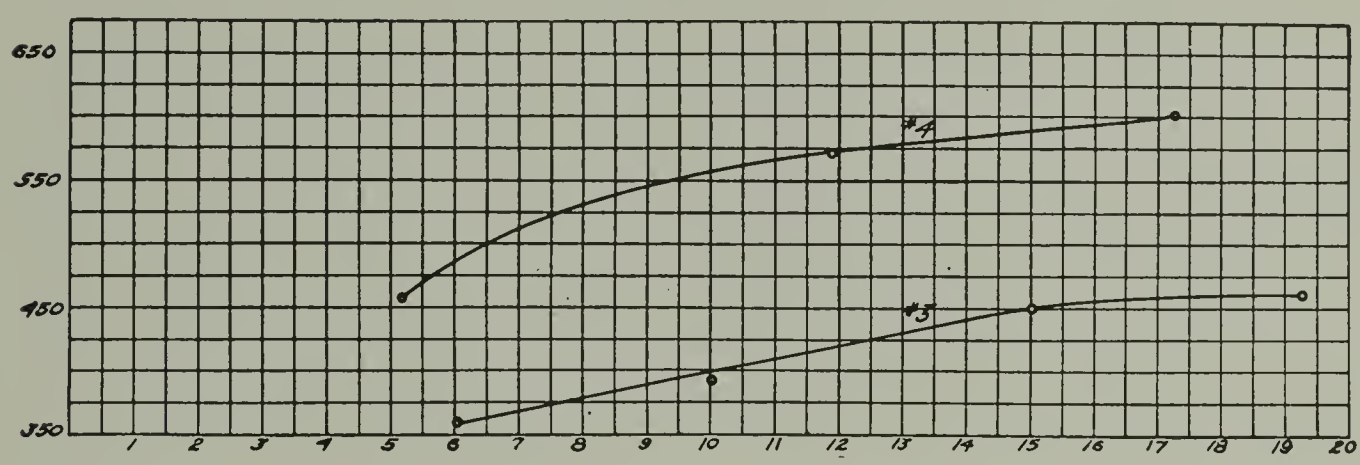
* Charts Nos. 3 to 7 were drawn to represent data secured on types of coolers that are not described in this article.

† See Appendix.

Large vs. Small Inner Pipes in Helical Cooler.

As outlined above, work carried out in the investigation allowed us to learn more concerning the effect on K of changing the diameter

Chart IX.—Velocity of Hot Water in Feet per Second. Conductivity per Hour per Degree per Square Foot.



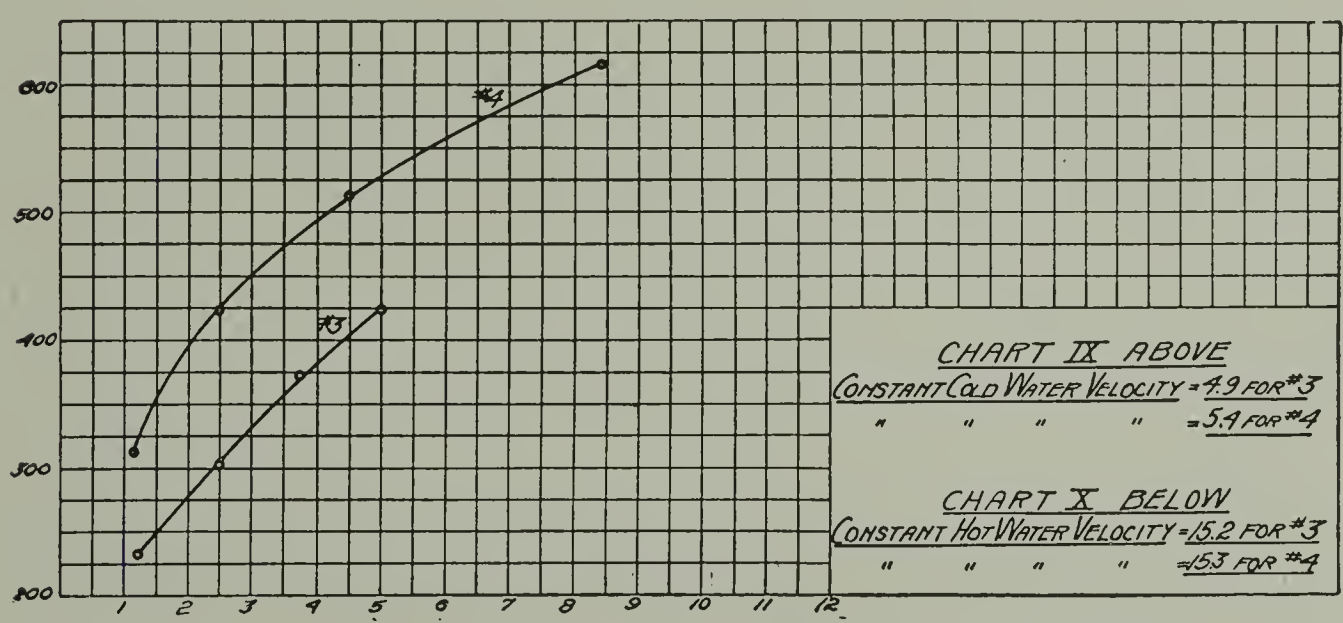


Chart X.—Velocity of Cold Water in Feet per Second. Conductivity per Hour per Degree per Square Foot.

of the inner pipe and incidentally to speculate further on factors which influence film velocity. The units employed for the work were larger in size. Cooler No. 3 consisted of 120 ft.—1½-inch lead pipe inside a 4-inch wrought iron pipe in the form of a helix six feet in diameter. Cooler No. 4 substituted a 2-inch lead coil for the 1½-inch coil. Otherwise there was no difference. Similar series of runs were conducted as in the case of the smaller coolers. The charts showing relationships of water velocities and conductivities are given above.

These charts picture consistently the greater K obtained with No. 4 cooler at average liquid velocities equal in each case. The magnitude of the differences rules out all chance of accident or inaccuracy. Our first hope was to explain this increase by some application of the film theory, and although subsequent work may confirm or reject our explanation, we will offer it for what it is worth.

It is reasonable to suppose that an increase in internal pipe

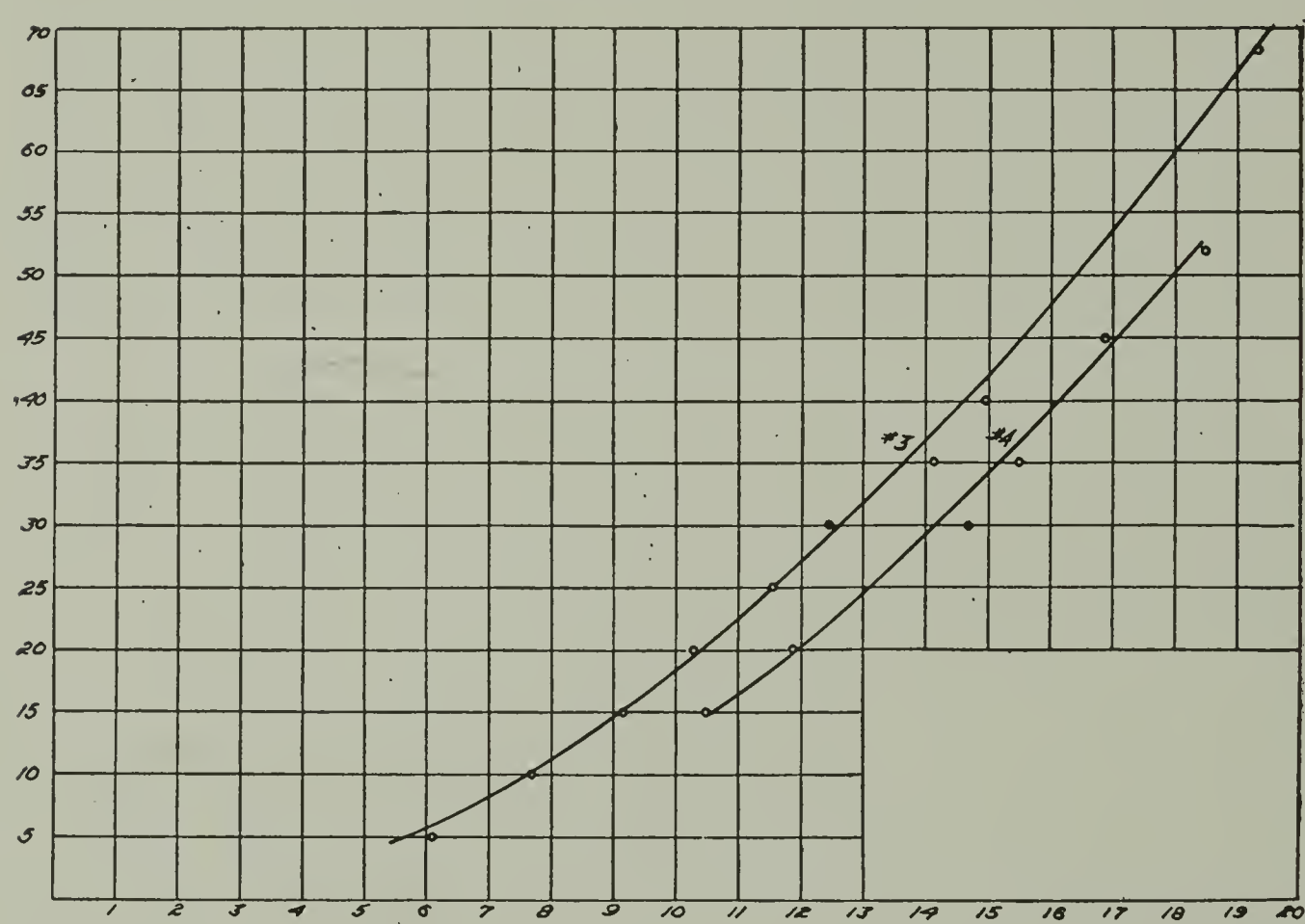


CHART XI.—Velocity in Feet per Second. Plot Showing Velocity in Inner Coils as Affected by Pump Pressure.

diameter will, by contracting the jacket space, increase the ratio of $\frac{\text{F.V.}}{\text{A.V.}}$ in the jacket. Granting this, the greater will be the K, as far as determined by jacket velocity, as we increase the internal pipe diameter. Conversely, as the inner pipe diameter is increased, we should expect a lowering in ratio $\frac{\text{F.V.}}{\text{A.V.}}$ within the inner coil, which in turn would counteract to a certain extent the jacket water ratio. Experimental results apparently prove that this compensating effect is only partial, which means that for a given increase in cross sec-

tional area of the inner coil, the F.V. increases much more in the jacket than the F.V. decreases in the inner coil.

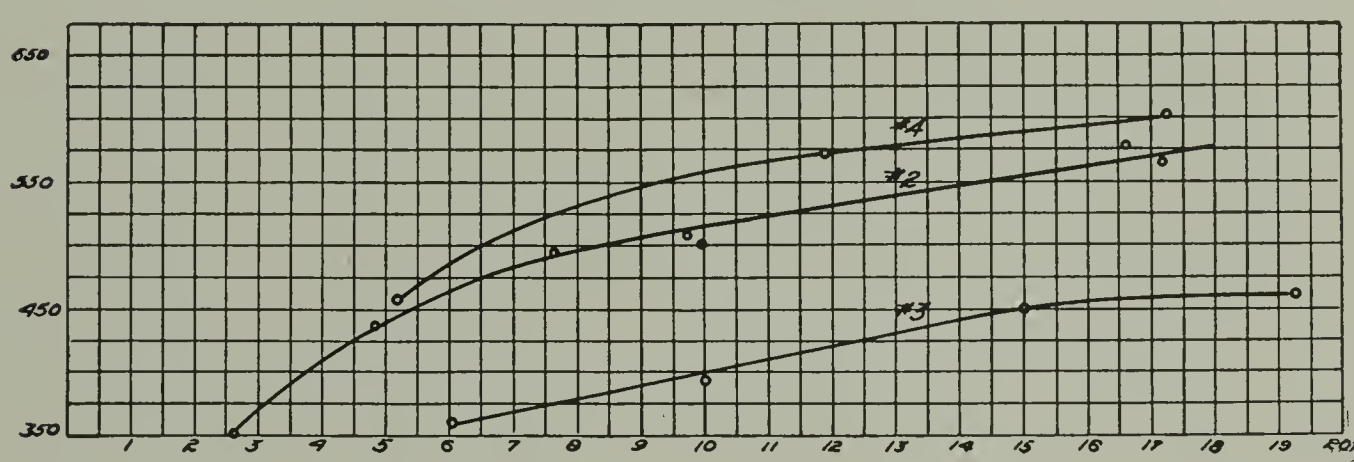
Chart XI illustrates the changes in average velocity of hot water with change in pump pressure for both No. 3 and No. 4 units. Although no data are available to cover the point, it is reasonable to suppose that similar curves for jacket water velocities would be reversed.

The curves plotted on Charts IX and X may be represented by equations.*

COOLER NO. 3.

$$K = \frac{57.5}{\frac{1}{1+5V_h^{.57}} + \frac{2.60}{1+10V_c^{.57}}} \quad . \quad . \quad . \quad (3)$$

CHART XII.—Velocity of Hot Water in Feet per Second. Conductivity per Hour per Degree per Square Foot.



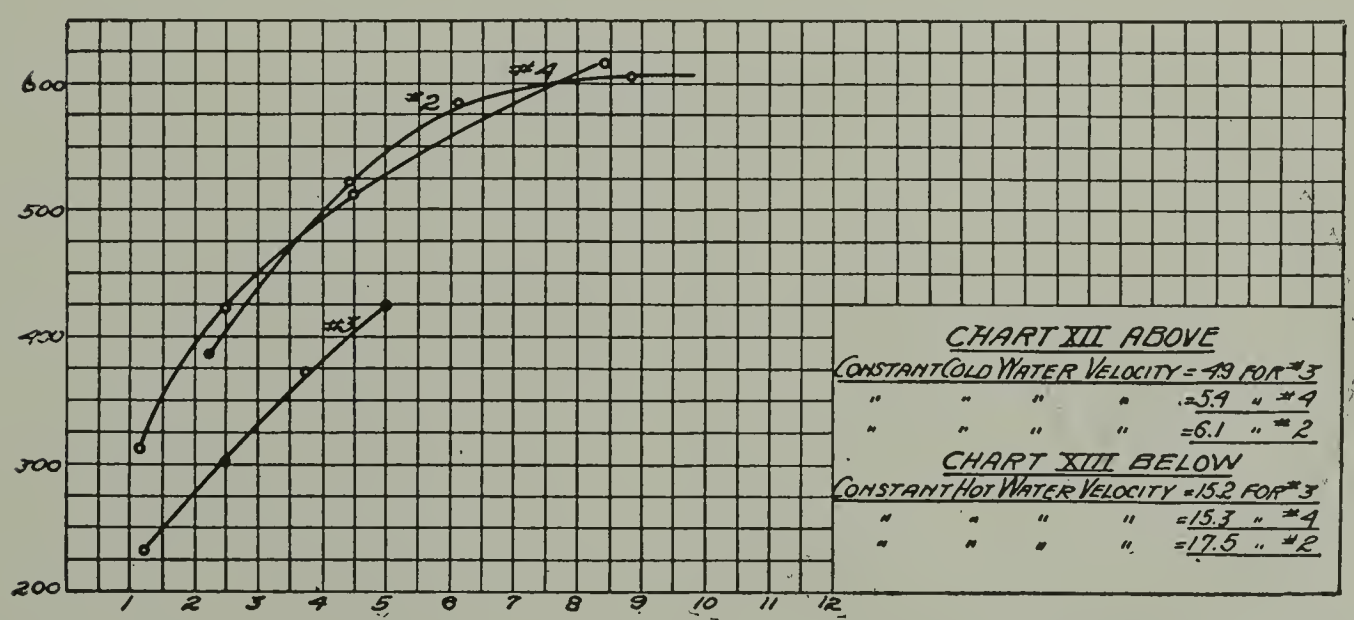


CHART XIII.—Velocity of Cold Water in Feet per Second. Conductivity per Hour per Degree per Square Foot.

* See Appendix.

Cooler No. 4.

$$K = \frac{80.0}{\frac{1}{1+5V_h^{.60}} + \frac{2.60}{1+10V_c^{.50}}}. \quad . \quad . \quad . \quad (4)$$

At zero velocity of hot and cold water, No. 3 cooler (by computation) has a conductivity of 15.95, whereas No. 4 cooler would show K equal 22.2. It is of interest to note that Molier's equation for zero velocities gives a value $K=30.75$.

Small vs. Large Helical Heat Interchangers.

In the above we have attempted to draw comparison between a straight pipe and helical cooler; also between helical coolers of different inner pipe diameters. It may be instructive to compare re-

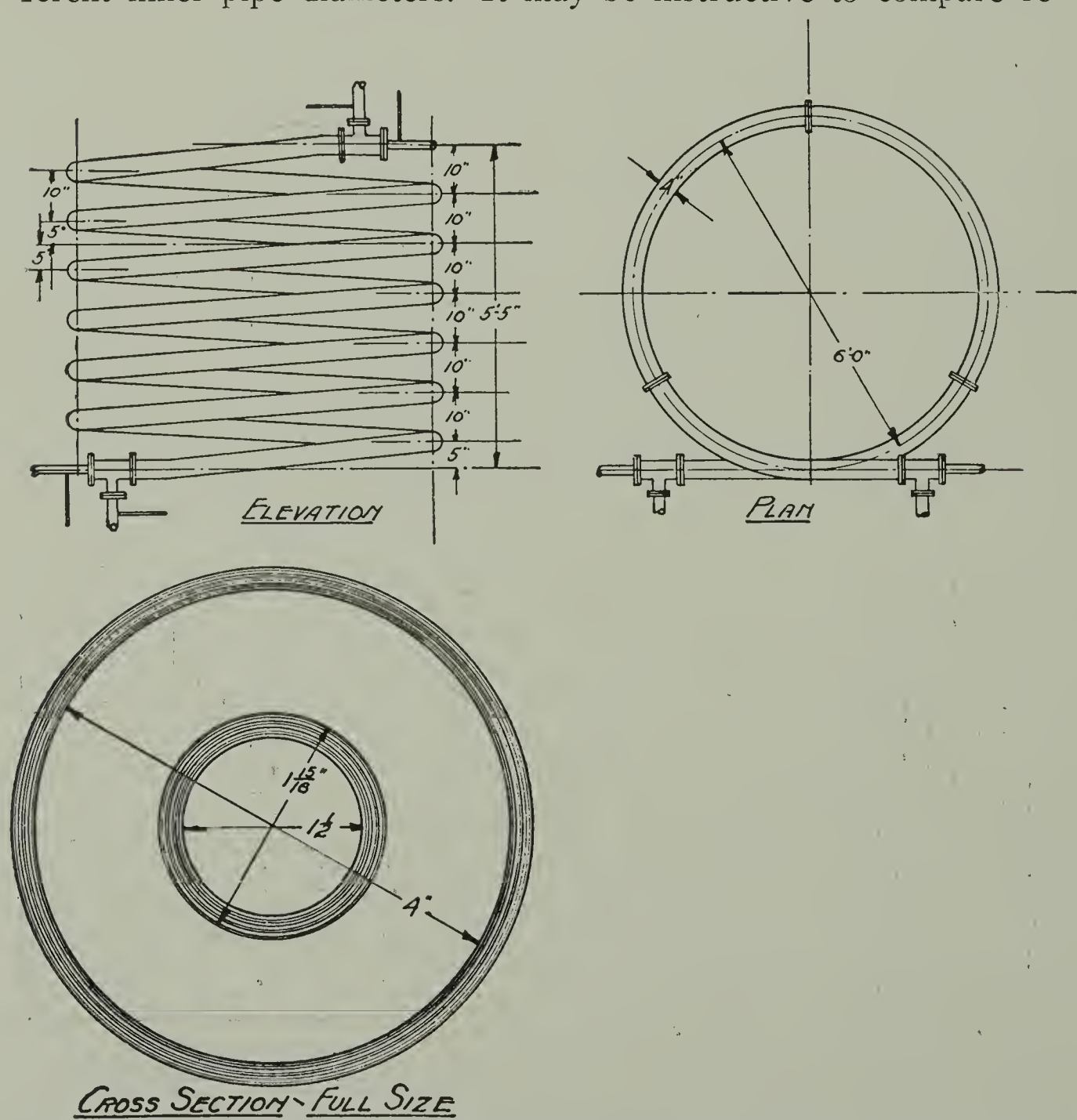


Fig. III.—Sketch Showing Two Views and Cross-section of Helical Coil. Cooler No. 3.

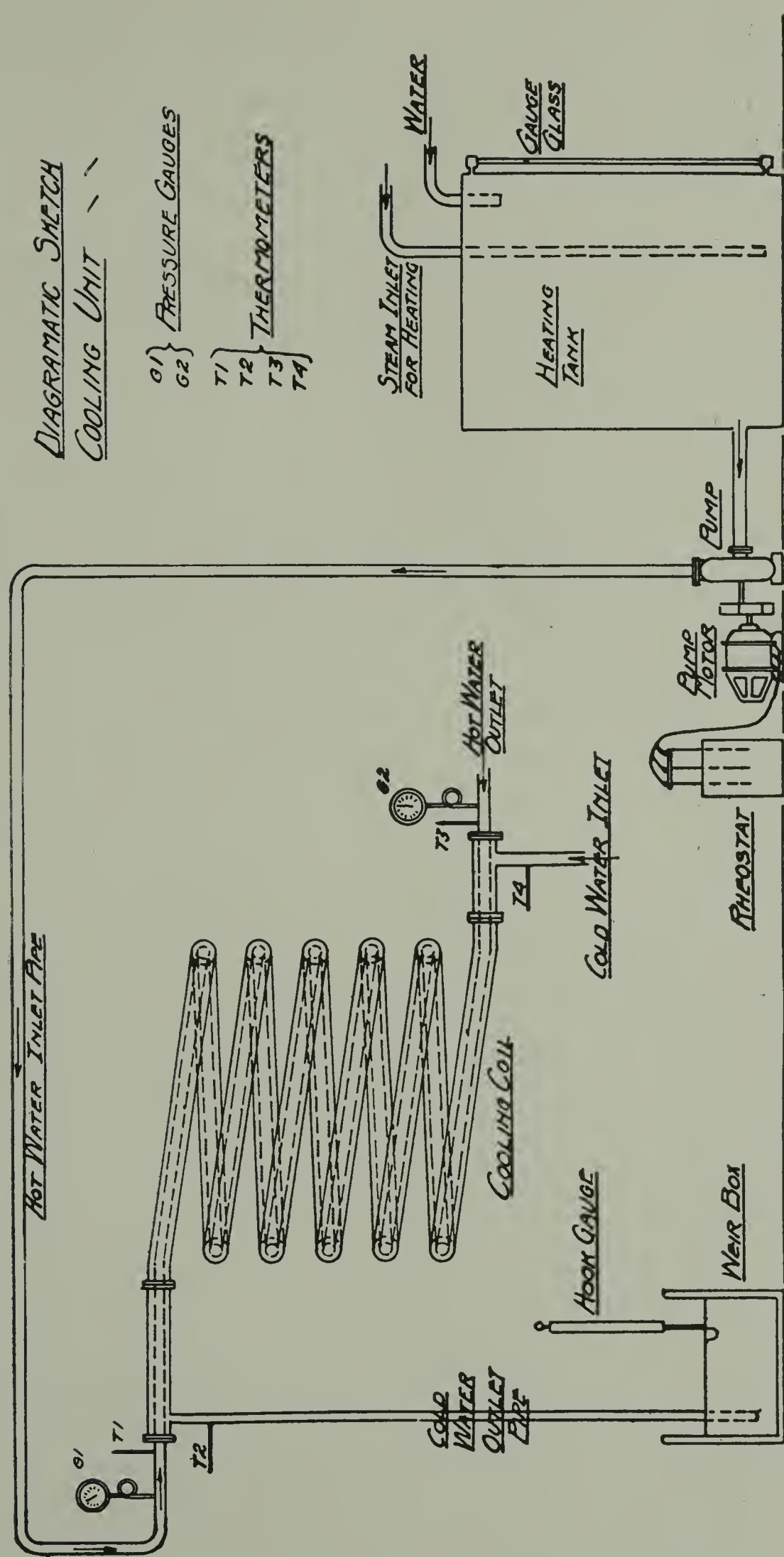

DIAGRAMATIC SKETCH
COOLING UNIT
PRESSURE GAUGES
G1
G2
THERMOMETERS
T1
T2
T3
T4
WATER
GAUGE GLASS
STEAM INLET FOR HEATING
HEATING TANK
PUMP
PUMP MOTOR
RHEOSTAT
HOT WATER OUTLET
COLD WATER INLET
HOT WATER INLET PIPE
COOLING COIL
HOOK GAUGE
WEIR BOX
COLD WATER OUTLET PIPE

FIG. IV.

sults obtained with the small No. 2 helical and large No. 3 and No. 4 helical units. Charts XII and XIII show the characteristics of these three coolers grouped for comparison.

It is noted that No. 4 cooler gives highest K values, with No. 2

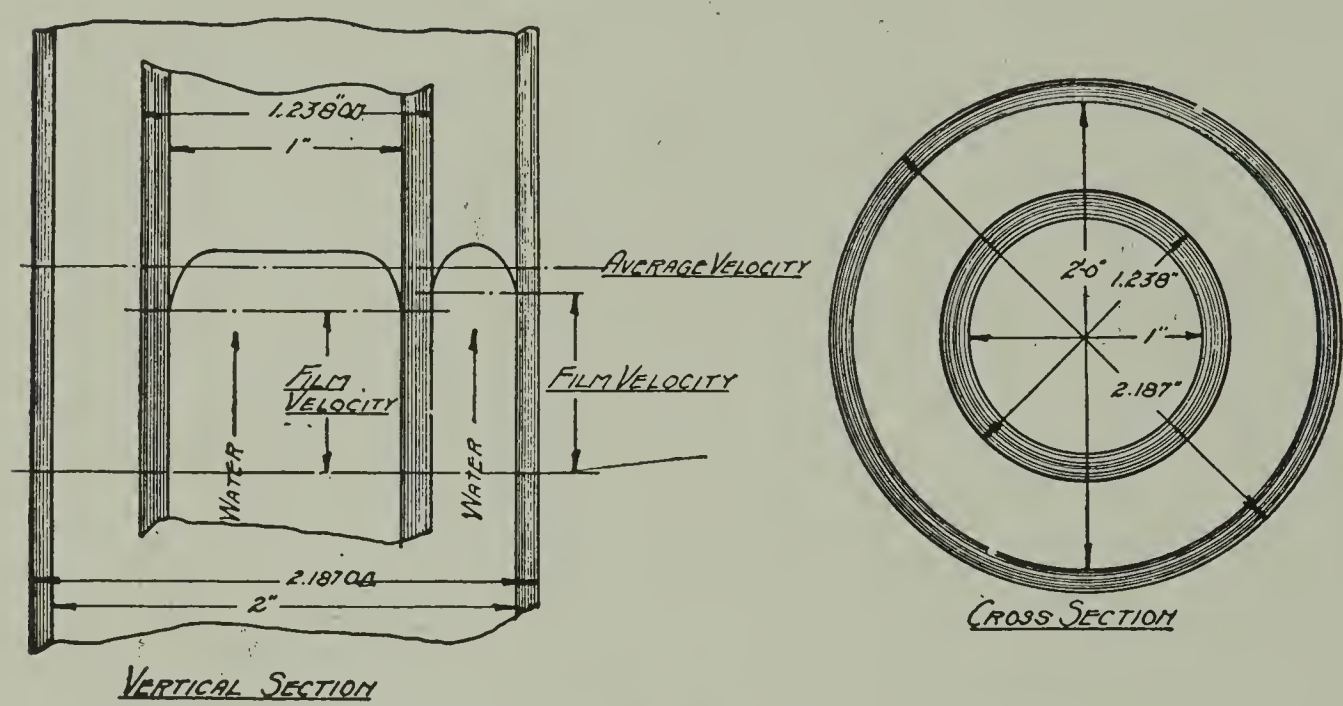


FIG. V.—Film Velocity in Double Pipe Cooler.

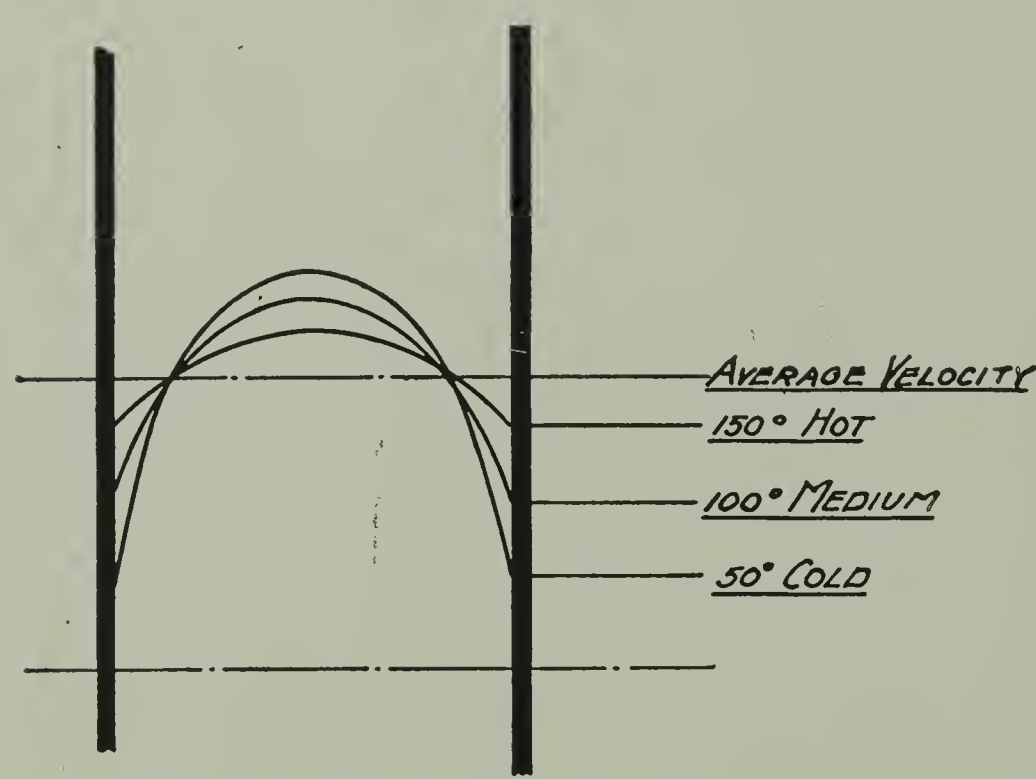


FIG. VI.—Diagram to Show Increases of Film Velocity as Fluidity Increases with Temperature.

cooler ranking a close second. No. 3 unit is appreciably lower in K. The difference in pipe diameters as well as diameter of entire helix make it difficult to theorize on similarities and differences.

We will, however, tabulate certain relationships which may

throw some light on the subject. If x=the distance from the inside surface of the jacket pipe to the center of the annular channel and y=the inside radius of the inner coil, then for each of these coolers

Cooler No. 2 ..... $\frac{x}{y} = .48$

" No. 3 ..... $\frac{x}{y} = .687$

" No. 4 ..... $\frac{x}{y} = .406$

Referring to Chart XII and XIII we note the conductivities increase inversely as the ratio listed. This appears to be in accordance with a theory advanced earlier in the paper; viz., that a narrowing in jacket area has greater effect in increasing film velocity than a corresponding enlargement of inner tube cross section would have in decreasing the film velocity.

Equation (2) and Equation (4) show the same close relationship as pictured by the curves covering No. 2 and No. 4 cooler.

Summary.

1. A double pipe heat interchanger in the form of a helix gives a marked increase in K over the same tubular parts put into the form of straight pipe lengths.

2. The film theory may account for this difference in K.

3. The increase in pump pressure required with the helical unit is small in comparison with the added increase in thermal efficiency.

4. Conductivity in all cases apparently increases slightly with increase in average temperatures in the system. This may be due to an increase in ratio of $\frac{\text{F.V.}}{\text{A.V.}}$ as is explained in the contents above.

5. A helical cooler consisting of a 2-inch pipe within a 4-inch pipe gives higher conductivity than a corresponding cooler equipped with a 1½-inch inner coil. A reason is offered for discussion.

6. Conductivities in helical coolers appear to vary inversely as the ratio of distance from inside surface of jacket pipe to center of jacket channel, to the radius of inner coil.

The writer acknowledges with thanks the valuable assistance of Frank M. Jones, who carried on the actual experimental work.

COOLER No. 1. COUNTER CURRENT.

Hot Water Velocity Varying. Cold Water Velocity Constant.

Initial T. hot H_2O.	Final T. hot H_2O.	Initial T. cold H_2O.	Final T. cold H_2O.	Velocity ft/sec hot H_2O.	Mean T. diff.	Velocity ft/sec cold H_2O	Gal. per min. hot.	Lbs./hr. hot.	Gal. per min. cold.	Lbs.hr. cold.	K.	Run No.
					Series 1							
112.3	91.4	49.5	71.2	13.54	40.4	6.39	32.37	16,185	38.15	19,075	475	16
132.6	105.1	50.0	79.7	15.3	55.8	6.22	37.48	18,740	37.13	18,565	524	18
149.5	115.7	49.8	85.8	13.2	63.9	6.29	32.34	16,170	37.57	18,785	486	17
168.3	127.4	49.2	92.7	13.3	75.6	6.15	32.6	16,300	36.7	18,350	501	15
			Avg.	13.8	Avg.	6.26				Avg.	496	
					Series 2							
110.1	87.6	50.9	69.9	10.27	38.5	5.88	25.12	12,560	35.12	17,560	417	22
134.9	100.7	51.2	78.3	9.89	52.5	5.89	24.22	12,110	35.19	17,595	448	21
151.7	110.1	50.0	83.8	10.3	63.8	6.15	25.24	12,620	36.7	18,350	469	19
169.8	120.7	51.7	90.5	10.2	73.7	6.15	24.9	12,450	36.7	18,350	438	20
			Avg.	10.15	Avg.	6.01				Avg.	443	
					Series 3							
112.4	82.4	50.9	68.2	7.35	37.5	6.13	17.9	8,950	36.59	18,295	406	23
131.3	95.9	55.4	78.4	7.25	46.6	5.42	17.7	8,850	32.31	16,155	382	24
152.0	105.8	55.0	84.3	7.75	59.3	5.65	18.9	9,450	33.65	16,845	418	25
167.2	111.5	59.0	89.3	7.13	64.9	5.14	17.2	8,600	30.56	15,280	419	26
			Avg.	7.39	Avg.	5.08				Avg.	406	

Series 4

112.1	78.9	59.3	70.7	4.39	29.1	4.74	10.7	5,350	28.23	14,115	347	28
132.2	84.5	59.7	73.7	3.76	39.5	5.88	9.19	4,595	35.12	17,560	315	29
147.0	86.3	57.2	75.0	4.05	47.4	5.29	9.85	4,925	31.5	15,750	358	30
167.9	92.2	59.0	80.9	3.69	55.8	5.14	9.0	4,500	30.56	15,280	347	27
			Avg.	3.97	Avg.	5.26				Avg.	342	

Cold Water Velocity Varying. Hot Water Velocity Constant

Series 5

111.2	97.5	69.8	79.9	17.2	29.4	10.6	42.2	21,100	63.6	31,800	559	90
133.1	112.1	71.6	86.0	18.0	43.8	10.7	44.0	22,000	64.3	32,150	599	92
151.1	123.4	71.6	91.0	18.4	56.0	10.5	45.0	22,100	62.8	31,400	621	88
171.3	137.7	70.7	97.1	17.9	71.8	10.2	44.0	22,000	60.9	30,450	585	89
			Avg.	17.8	Avg.	10.5				Avg.	591	

Series 6

111.5	98.9	73.2	84.2	17.2	26.7	8.06	43.1	21,550	48.12	24,060	568	98
132.1	113.9	72.5	90.9	17.5	41.4	8.06	42.8	21,400	48.12	24,060	535	97
154.2	130.3	75.7	100.7	17.6	54.4	8.06	44.3	22,150	48.12	24,060	553	100
170.9	142.0	75.5	106.0	17.6	65.6	8.06	44.2	22,100	48.12	24,060	553	101
			Avg.	17.5						Avg.	552	

Series 7

113.0	101.3	71.6	85.8	17.4	29.0	6.3	42.7	21,350	37.6	18,800	489	94
130.3	114.1	72.9	94.5	17.3	38.6	6.3	42.3	21,150	37.6	18,800	504	95
149.0	128.1	74.7	102.4	16.3	50.7	6.3	39.8	19,900	37.6	18,800	466	96
165.5	140.0	71.6	110.7	18.0	66.1	6.3	44.2	22,100	37.6	18,800	484	93
			Avg.	17.2						Avg.	485	

COOLER No. 2. COUNTER CURRENT

Hot Water Velocity Varying. Cold Water Velocity Constant

Initial T. hot H_2O.	Final T. hot H_2O.	Initial T. cold H_2O.	Final T. cold H_2O.	Velocity ft/sec hot H_2O.	Mean T. diff.	Velocity ft/sec cold H_2O.	Gal. per min. hot.	Lbs./hr. hot.	Gal. per min. cold.	Lbs./hr. cold.	K.	Run No.
					Series 8							
111.2	87.6	68.9	80.4	7.3	24.2	6.13	17.9	8,950	36.59	18,295	496	63
131.0	98.1	69.1	86.9	7.7	35.9	6.13	18.9	9,450	36.59	18,295	492	64
149.3	106.0	68.0	90.1	7.8	47.8	6.13	19.1	9,550	36.59	18,295	492	65
167.0	115.1	68.2	96.4	8.0	57.5	6.13	19.6	9,800	36.59	18,295	502	66
			Avg.	7.7						Avg.	496	
					Series 9							
111.5	87.4	70.1	80.6	6.75	23.4	6.13	16.51	8,255	36.59	18,295	483	43
129.2	93.0	69.0	84.2	6.25	33.6	6.13	15.3	7,650	36.59	18,295	468	42
148.4	103.4	70.7	92.1	7.0	43.5	6.13	17.1	8,550	36.59	18,295	504	40
171.5	113.9	69.2	98.4	7.3	57.8	6.13	17.9	8,950	36.59	18,295	508	41
			Avg.	6.8						Avg.	490	
					Series 10							
114.8	83.8	67.8	78.6	4.8	24.8	6.13	11.72	5,860	36.59	18,295	416	44
131.1	86.9	63.5	78.9	5.2	36.0	6.13	12.7	6,350	36.59	18,295	443	48
150.2	94.2	62.6	84.7	4.9	46.6	6.13	12.05	6,600	36.59	18,295	451	49
165.3	96.8	63.8	85.1	5.08	53.2	6.13	12.4	6,200	36.59	18,295	453	50
			Avg.	4.9						Avg.	441	

					Series 11							
110.6	74.6	67.2	73.2	2.67	18.5	6.13	6.55	3,275	36.59	18,295	362	54
132.0	79.7	67.2	76.8	2.64	28.7	6.13	6.46	3,230	36.59	18,295	337	53
149.9	77.7	61.7	77.0	2.69	37.5	6.13	6.6	3,300	36.59	18,295	361	51
169.5	86.3	66.3	83.1	2.69	45.5	6.13	6.6	3,300	36.59	18,295	343	52
			Avg.	2.67						Avg.	351	
					Series 12							
111.9	95.5	63.7	80.4	15.5	31.9	6.13	37.9	18,950	36.59	18,295	553	55
133.0	109.5	61.5	87.6	16.5	46.9	6.13	40.5	20,250	36.59	18,295	605	56
150.4	123.8	64.6	95.9	17.7	56.8	6.13	43.4	21,700	36.59	18,295	578	57
169.1	136.9	68.3	105.1	17.0	66.5	6.13	41.6	20,800	36.59	18,295	572	58
			Avg.	16.7						Avg.	577	
					Series 13							
111.4	93.2	72.5	83.8	9.56	24.0	6.13	23.4	11,700	36.59	18,295	504	72
127.2	104.2	72.5	91.0	10.5	34.0	6.13	25.8	12,900	36.59	18,295	497	71
150.1	112.5	71.6	96.8	8.9	46.9	6.13	21.7	10,850	36.59	18,295	494	73
169.0	124.1	70.7	102.4	10.1	59.8	6.13	24.8	12,400	36.59	18,295	541	75
			Avg.	9.75						Avg.	509	
					Cold Water Velocity Varying. Hot Water Velocity Constant.							
					Series 14							
112.0	96.4	70.1	81.1	16.1	28.1	8.9	39.5	19,250	53.2	26,500	576	76
131.0	109.2	70.9	87.4	16.6	40.5	8.9	40.7	20,350	53.2	26,500	622	79
149.5	121.6	71.1	93 5	16.7	53.1	8.9	40.9	20,450	53.2	26,500	602	77
168.8	133.0	69.8	99.1	16.5	66.3	8.9	40.4	20,200	53.2	26,500	620	78
			Avg.	16.5						Avg.	605	

COOLER No. 2. COUNTER CURRENT—*Continued*

Cold Water Velocity Varying. Hot Water Velocity Constant.

Initial T. hot H_2O.	Final T. hot H_2O.	Initial T. cold H_2O.	Final T. cold H_2O.	Velocity ft/sec hot H_2O.	Mean T. diff.	Velocity ft/sec cold H_2O.	Gal. per min. hot.	Lbs./hr. hot.	Gal. per min. cold.	Lbs./hr. cold.	K.	Run No.
					Series 15							
111.9	95.5	63.7	80.4	15.5	31.9	6.13	37.9	18,950	36.59	18,295	553	55
133.0	109.5	61.5	87.6	16.5	46.9	6.13	40.5	20,250	36.59	18,295	605	56
150.4	123.8	64.6	95.9	17.7	56.8	6.13	43.4	21,700	36.59	18,295	578	57
169.1	136.9	68.3	105.1	17.0	66.5	6.13	41.6	20,800	36.59	18,295	572	58
			Avg.	16.7						Avg.	577	
					Series 16							
113.0	101.3	70.1	90.7	16.1	26.5	4.48	39.5	19,750	26.75	13,375	496	80
131.7	114.4	70.3	97.9	16.6	38.7	4.48	40.7	20,350	26.75	13,375	517	82
151.3	128.7	68.7	106.7	16.0	51.8	4.48	41.4	20,700	26.75	13,375	513	83
170.2	140.5	70.1	117.5	16.3	61.1	4.48	40.0	20,000	26.75	13,375	553	81
			Avg.	16.3						Avg.	519	
					Series 17							
112.8	104.9	71.6	96.3	16.9	23.9	2.26	41.3	20,650	13.5	6,750	388	85
133.3	122.0	73.4	111.4	16.7	33.5	2.26	41.0	20,500	13.5	6,750	393	87
148.8	134.2	73.2	121.6	15.9	43.9	2.26	38.9	19,450	13.5	6,750	368	86
165.7	146.3	71.6	132.3	15.4	51.3	2.26	37.6	18,800	13.5	6,750	404	84
			Avg.	16.2						Avg.	388	

COOLER No. 3. COUNTER CURRENT

Cold Water Velocity Varying. Hot Water Velocity Constant

Initial T. hot H_2O.	Final T. hot H_2O.	Initial T. cold H_2O.	Final T. cold H_2O.	Pump Pressure.	Velocity ft/sec hot H_2O.	Velocity ft/sec cold H_2O.	Mean T. diff.	Gal. per min. hot.	Lbs/hr hot.	Gal. per min. cold.	Lbs/hr cold.	K.	Run No.
					Series 18								
111.0	88.3	58.6	70.0	..	14.9	3.77	35.1	82.6	41,300	113	56,500	396	154
133.2	103.1	58.1	77.1	..	15.0	3.77	50.6	82.7	41,350	113	56,500	358	156
149.9	113.1	58.4	82.2	..	15.2	3.77	61.5	84.0	42,000	113	56,500	372	157
169.0	125.6	59.3	89.0	..	15.1	3.77	72.5	83.5	41,750	113	56,500	363	160
					Avg. 15.1	3.77					Avg.	372	
					Series 19								
110.2	92.0	59.1	75.2	..	14.9	2.5	35.6	82.3	41,150	75.8	37,900	296	155
130.6	106.5	58.4	83.1	..	15.1	2.5	50.4	83.4	41,700	75.8	37,900	290	158
150.5	118.4	59.0	88.0	..	14.9	2.5	61.1	82.5	41,250	75.8	37,900	314	161
172.0	133.5	59.1	99.1	..	15.3	2.5	75.7	84.6	42,300	75.8	37,900	313	162
					Avg. 15.0	2.5					Avg.	303	
					Series 20								
111.1	98.6	58.1	76.2	..	15.0	1.25	37.7	83.0	41,500	37.4	18,700	200	163
130.0	111.5	58.4	89.8	..	15.1	1.25	46.5	83.4	41,700	37.4	18,700	240	164
149.5	127.4	59.3	98.9	..	16.6	1.25	59.1	91.6	45,800	37.4	18,700	248	165
167.0	140.0	55.4	104.4	..	15.3	1.25	73.3	84.5	42,250	37.4	18,700	225	166
					Avg. 15.5	1.25					Avg.	232	

COOLER No. 3. COUNTER CURRENT—*Continued*

Initial T. hot H_2O.	Final T. hot H_2O.	Initial T. cold H_2O.	Final T. cold H_2O.	Pump Pressure.	Velocity ft/sec hot H_2O.	Velocity ft/sec cold H_2O.	Mean T. diff.	Gal. per min. hot.	Lbs./hr hot.	Gal. per min. cold.	Lbs/hr. cold.	K.	Run No.
					SERIES 21								
111.1	86.3	57.2	68.0	40	15.2	4.8	35.7	84.1	42,050	145.0	72,500	424	136
131.7	96.5	58.1	72.8	40	15.2	5.3	48.2	84.0	42,000	159.0	79,500	445	137
149.0	108.2	58.3	78.3	40	14.95	4.9	59.3	82.5	41,250	147.0	73,500	413	138
168.0	118.5	58.7	80.0	40	15.0	5.1	70.7	83.0	41,500	153	76,500	421	139
					Avg. 15.1	5.0					Avg.	425	
					HOT WATER VELOCITY VARYING. COLD WATER VELOCITY CONSTANT.								
					SERIES 22								
111.1	86.3	57.2	68	40	15.2	4.8	35.7	84.1	42,050	145	72,500	424	136
131.7	96.5	58.1	72.8	..	15.2	5.3	48.2	84	42,000	159	79,500	445	137
149.0	108.2	58.3	78.3	..	14.95	4.9	59.3	82.5	41,250	147	73,500	413	138
168.0	118.5	58.7	80.0	..	15.0	5.1	70.7	83.0	41,500	153	76,500	421	139
					Avg. 15.1	5.0					Avg.	425	
					SERIES 23								
109.9	80.4	57.2	66.7	17.5	9.64	4.7	32.3	53.2	26,600	141	70,500	352	141
130.5	90.1	57.5	71.1	..	10.1	4.7	44.8	55.7	27,750	142	71,000	347	142
149.1	97.3	57.3	74.0	..	10.2	4.9	55.5	56.3	28,150	148	74,000	382	143
167.3	105.6	58.6	79.0	..	10.2	5.2	64.2	57.0	28,500	157	78,500	398	144
					Avg.10.06	4.9					Avg.	369	

SERIES 24

109.8	73.5	58.4	66.0	5	6.25	4.7	27.0	34.6	17,300	142	71,000	339	145
129.9	78.8	58.8	68.2	..	6.05	4.8	37.6	33.4	16,700	146	73,000	370	146
149.5	86.5	58.8	72.2	..	6.2	4.7	48.4	34.2	17,100	142	71,000	324	1 7
169.5	90.6	58.8	74.5	..	6.2	4.9	57.8	34.2	17,100	149	74,500	301	148
					Avg. 6.1	4.8					Avg.	333	

SERIES 25

110.8	91.4	59.3	70.9	68	19.3	4.9	36.3	106.8	53,000	147	73,500	412	150
132.0	104.0	57.0	73.0	..	19.3	5.2	49.4	107.1	53,550	156	78,000	442	151
151.2	114.8	57.9	77.0	..	19.3	6.0	65.0	107.1	53,550	181	90,500	437	152
171.1	130.1	58.2	85.3	..	19.5	4.6	73.0	108.0	54,000	139	69,500	440	153
					Avg. 19.3	5.1					Avg.	433	

COOLER No. 4. COUNTER CURRENT

Hot Water Velocity Varying. Cold Water Velocity Constant

Initial T. hot H_2O.	Final T. hot H_2O.	Initial T. cold H_2O.	Final T. cold H_2O.	Pump Pressure.	Velocity ft/sec hot H_2O.	Mean T. diff.	Gal. per min. hot.	Lbs/hr hot.	Gal. per min. cold.	Lbs/hr cold.	Velocity ft/sec cold H_2O.	K.	Run No.
					Series 26								
113.5	95.4	55.7	72.4	52	18.9	40.3	185.0	92,500	140.3	70,150	5.5	603	168
133.0	110.0	55.5	80.2	50	18.3	53.8	179.0	89,500	130.1	65,050	5.1	555	169
151.0	119.0	55.7	83.0	45	16.9	60.0	165.5	82,750	145.5	72,750	5.7	658	167
171.0	128.1	54.9	87.2	38	15.3	78.9	150.0	75,000	144.0	72,000	5.7	592	170
					Avg. 17.3					Avg.	5.5	577	
					Series 27								
112.0	88.0	53.7	68.7	20	11.9	38.5	116.8	58,400	145.5	72,750	5.7	528	174
133.0	101.4	55.1	77.2	20	12.0	51.1	118.0	59,000	124.5	62,250	4.9	530	171
151.0	110.0	55.5	79.7	20	12.0	62.5	117.5	58,750	146.0	73,000	5.7	560	172
170.0	120.0	55.4	84.9	20	11.9	74.5	117.0	58,500	146.2	73,100	5.7	570	173
					Avg. 11.9					Avg.	5.5	547	
					Series 28								
112.9	75.0	53.9	63.9	not indicated	5.3	33.2	51.8	25,900	144.0	72,000	5.7	428	175
130.8	81.9	54.3	68.9		5.3	42.6	52.2	26,100	134.8	67,200	5.3	436	176
152.0	86.5	53.8	72.6		4.8	52.7	46.5	23,250	125.0	62,500	4.9	420	177
169.4	95.0	54.1	77.5		5.4	63.3	52.7	26,350	128.0	64,000	5.0	448	178
					Avg. 5.2					Avg.	5.2	433	

					Series 29								
110.8	88.3	53.1	65.3	35	15.3	40.3	150.5	75,250	190.0	95,000	7.5	611	196
132.0	100.6	52.6	70.0	35	15.4	54.4	151.5	75,750	190.0	95,000	7.5	637	197
147.8	110.6	53.2	74.4	35	14.9	64.7	146.0	73,000	187.0	93,500	7.4	611	198
169.0	123.5	53.9	80.3	35	15.0	79.4	147.0	73,500	187.0	93,500	7.4	612	199
					Avg. 15.1					Avg.	7.45	618	
					Series 30								
112.0	99.1	55.5	81.6	35	15.5	36.6	152.0	76,000	63.4	31,700	2.5	389	183
130.0	109.7	50.9	85.8	35	15.5	51.2	152.0	76,000	63.4	31,700	2.5	437	191
150.9	126.9	54.5	99.9	35	15.5	61.0	152.0	76,000	63.4	31,700	2.5	434	185
169.0	138.5	51.0	106.2	30	14.7	74.5	144.0	72,100	63.4	31,700	2.5	430	186
					Avg. 15.3					Avg.	2.5	422	
					Series 31								
112.3	94.6	54.5	73.3	35	15.5	38.5	151.5	75,750	113.4	56,700	4.5	506	179
132.0	107.6	54.2	81.0	35	15.6	51.3	153.0	76,500	113 4	56,700	4.5	517	180
151.5	120.8	54.5	87.8	35	15.7	66.4	153.2	76,600	113.4	56,700	4.5	518	181
170.0	132.5	54.8	94.0	35	15.3	78.3	150.0	75,000	113.4	56,700	4.5	515	182
					Avg. 15.5					Avg.	4.5	514	
					Series 32								
111.7	101.9	52.3	80.5	35	15.4	39.6	151.0	75,500	30.0	15,000	1.2	271	188
131.0	114.7	49.9	85.6	35	15.7	54.5	154.0	77,000	30.0	15,000	1.2	335	190
149.9	132.8	53.1	103.5	35	15.8	61.5	154.5	77,250	30.0	15,000	1.2	312	189
173.0	150.6	52.9	113.7	30	14.7	77.0	143.5	71,750	30.0	15,000	1.2	335	187
					Avg. 15.4					Avg.	1.2	313	

TABLE No. 1

DIFFERENCES IN PRESSURES IN INNER COIL AT OUTLET AND INLET OF COOLER No. 4

Hot Water Inlet.	Hot Water Outlet.	Hot Water Inlet.	Hot Water Outlet.
0	0.5	25	3.0
5	0.75	30	3.5
10	1.25	40	4.5
15	2.0	42.5	5.0
20	2.5		

TABLE No. 2

CORRESPONDING PUMP PRESSURES AND VELOCITIES OF HOT WATER

Cooler No. 3		Cooler No. 4.	
Pump Pressure.	Velocity.	Pump Pressure.	Velocity.
5	6.1	15	10.5
10	7.70	20	11.9
15	9.17	30	14.7
20	10.32	35	15.5
25	11.61	45	16.9
30	12.48	52	18.5
35	14.12		
40	15.0		
68	19.3		

APPENDIX

Method

Water was heated to the desired temperature in a large iron tank by means of live steam. A centrifugal pump, motor driven, circulated the hot water; the velocity being regulated by means of a rheostat. The amount of water pumped out of the tank was measured by means of the drop in a gauge glass.

Cold water was obtained from the river and its velocity regulated by a valve. Its flow was measured by means of a weir and hook gauge.

Temperature changes were observed through four thermometers directly immersed in the flowing liquids. Melted sulphur was used

to seal these in the various apertures. The thermometers were placed as near the inlets and exits of the cooler as possible. Runs were made at temperatures approximating 110°-130°-150°-170° Fahrenheit scale.

Data on Apparatus Used

Tank

Height 5 ft. 6 in., diam. 4 ft. 7 in., capacity 677 gal.
Water heated by live steam.
Graduated water gauge on side to measure outflow.

Pump

Lawrence, vortex 1½ in. discharge, single side suction, gauge 5 ft. from discharge to measure pressure.

Motor

Westinghouse 5 H.P. constant speed, 60 cycle, 2 phase, 440 volts.

Weir Box

Length 12 ft, width 1 ft. 4 in., depth 1 ft. 3½ in.; contracted type, crest length 4.87 in. sharp crested. Channel of approach lined with tin, two vertical baffle plates serving to lessen surging.

Hook Gauge

Of brass, reading to 1/100-in.

Remarks

No. 1 straight cooler consisted of three 20 in. lengths of 2 ft. iron pipe containing 1 in. lead pipe. A surface of 36 in. of lead pipe (at the two ends) was exposed to the air and not affected by the cooling water. The under surface of the lead pipe was beaded at intervals to center it.

No. 2 helical cooler consisted of several sections of iron pipe bent to form a spiral form. Three sections constituted one turn and were united by flanges. The overall dimensions were 36 in. diameter and 40 in. high. The lead coil was likewise beaded (or provided with lugs) at intervals to center it.

No. 3 helical cooler was similar to No. 2 except that 4 in. iron pipe was used for a jacket; 3 flanged sections to a turn; 19 sections in all (or $6\frac{1}{3}$ turns). The inner lead pipe was not beaded (or "lugged") but merely laid loosely inside the jacket.

No. 4 helical cooler had the same jacket as No. 3 but contained a 2 in. instead of $1\frac{1}{2}$ in. lead pipe.

Calculations

Mean Temperature Difference

The logarithmic mean was taken according to the formula (for counter current).

$$T = \frac{(t_1 - t_4) - (t_2 - t_3)}{\log_e \frac{(t_1 - t_4)}{(t_2 - t_3)}}$$

where T = mean temperature difference;
t_1 = initial hot water temperature;
t_2 = final " " "
t_3 = initial cold " "
t_4 = final " " "

Dimensions of Coolers

Cooler No.	Material.	Outer Dia. In.	Inner Dia. In.	I. D. Cross-section, sq. ft.	Total (Mean) Surface, sq. ft.	Length.
No. 1 straight outer coil	Straight iron pipe	2.187	2.0	.0218	....	60′
Inner coil.....	Straight lead pipe	1.238	1.0	.00545	17.6	60′
No. 2 helical outer coil	Bent iron pipe		Same	as above		
Inner coil.....	Helical lead pipe		Same	as above		
No. 3 helical outer coil	Bent iron pipe	4.5	4.0	.0873	....	120′ 4″
Inner coil.....	Helical lead pipe	1.937	1.5	.0123	60.6	120′ 4″
No. 4 helical outer coil	Bent iron pipe	4.5	4.0	.0873	....	120′ 4″
Inner coil.....	Helical lead pipe	2.375	2.0	.0218	68.8	120′ 4″

Conductivity

K, the conductivity constant, or B.t.u. extracted per hour, per degree F., per square foot of surface is determined by:

$$K = \frac{A \times B}{T \times D}$$

Where A = pounds of hot water flowing per hour;

B = drop in temperature of hot water $(t_1 - t_2)$;

T = mean temp. difference;

D = sq. ft. of cooling surface.

Velocity

$$V = \frac{\text{cu. ft. per second flowing}}{\text{cross section of pipe (in sq. ft.)}}$$

Weir

The weir flow was calculated from the well known Francis formula.

$$Q = 3.33(l - 0.2h)h^{3/2};$$

Where Q = discharge in cu. ft. per second;

l = width of notch, in feet;

h = height of water above notch level, in ft.

The accuracy of this formula (for this particular weir) and reading of the hook gauge was actually checked by running the overflow into a tank and measuring the quantity delivered.

Empirical Equation of Velocity—K curve

Since the velocities of both hot and cold water are independently variable, the desired equation connecting K with water velocity will contain three variables. In the cases in which one velocity was held constant while the other was varied, and then vice versa, the relation of hot and cold water velocities to K can be studied separately. The simplest way to do this is to plot on logarithmic paper values of K against those of the variable velocity, which tests for a relation of the form $K = AV^b$, where A and b are constants, or indirectly also for similar form $K = AV^b + C$, where C is also a constant. In the former case the graph approximates a straight line, in the latter, a curve which is concave upward if C is positive, downward if C is negative. The experimental data give a graph which is a curve concave downward; this is an absurd result physi-

cally since it means that at zero velocity K is negative. Another form of equation should be sought.

The form which is suggested by Hausbrand—("Evap., Cond., and Cooling App." Revised Ed., p. 305), namely:

$$K = \frac{1}{1+3.3V_h^{0.50}} + \frac{1}{1+3.3V_c^{0.50}} \text{ (English units)}$$

has been found to satisfy the experimental data quite accurately, given slight changes in some of the numerical constants. An equation as this cannot be directly fitted to data, and a method of "cut and try" until the errors are below the experimental limit of accuracy is the only available method; on this account the constants are mainly round numbers, and the fit is not as close as might result from some method of direct solution.

STRAIGHT NO. 1

Hot.	Cold.	Calc. K.	Obs. K.
13.8	6.26	478	496
10.15	6.01	446	443
7.39	5.08	395	406
3.97	5.26	348	342
17.8	10.5	606	591
17.5	8.06	550	552
17.2	6.3	499	485

$$\frac{62.7}{\frac{1}{1+5V_h^{0.57}} + \frac{2.60}{1+10V_c^{0.57}}}$$

HELICAL NO. 2

Hot.	Cold.	Calc. K.	Obs. K.
7.7	6.13	488	496
6.8	6.13	476	490
4.9	6.13	443	441
2.67	6.13	379	351
16.7	6.13	560	577
9.75	6.13	511	509
16.5	8.9	635	605
16.3	4.48	497	519
16.2	2.26	386	388

$$\frac{76.2}{1+5V_h^{0.50}+1+10V_c^{0.50}}$$

HELICAL NO. 3

Hot.	Cold.	Calc. *K*.	Obs. *K*.
15.1	5.0	409	425
15.1	3.77	366	372
15.0	2.5	309	303
15.5	1.25	230	232
19.3	5.1	427	433
10.06	4.9	378	369
6.1	4.8	341	333

$$\frac{57.5}{\frac{1}{1+5V_h^{0.57}}+\frac{2.60}{1+10V_c^{0.57}}}$$

HELICAL NO. 4

Hot.	Cold.	Calc. *K*.	Obs. *K*.
17.3	5.5	569	577
11.9	5.5	536	547
5.2	5.2	449	433
15.1	7.45	620	618
15.3	2.5	418	422
15.5	4.5	519	514
15.4	1.2	314	313
18.5	7.5	640	648

$$\frac{80.0}{\frac{1}{1+5V_h^{0.60}}+\frac{2.60}{1+10V_c^{0.50}}}$$

DISCUSSION

The PRESIDENT: The matter which Mr. Richter has presented is of extreme interest, and I hope it will be the subject of discussion.

The SECRETARY: May I ask if Mr. Richter has any data on the different materials in his pipes?

Mr. RICHTER: In these experiments we used the lead only, inasmuch as it was a direct plant problem. We have in mind to follow it up in copper and iron, and probably antimony lead, but have not done so.

The SECRETARY: Do you think you would get the same ratios?

Mr. RICHTER: Yes, I do. I think as we increase the velocity of hot and cold water we would approach the same curve shown on this chart. As you increase the velocities of the two liquors in question, the material makes less difference.

The SECRETARY: But of course you would get higher conductivity if you used a metal like copper?

Mr. Richter: No, I don't think so.

The Secretary: That is what I was trying to get at.

Dr. Moore: We conducted several experiments with lead and iron. The conductivity of these metals is at low velocities far apart. Those were before Mr. Richter's experiments, and at high velocities they came right together. Also, where I tried experiments of corrugated pipe, compared with smooth straight pipe, the corrugated pipe gave a higher conductivity for the low velocities but at high velocities the conductivity of the smooth straight pipe was greater than that for the corrugated pipe.

The President: Do you mean corrugated pipe or spiral?

Dr. Moore: Rolled in rings. It will give a higher conductivity for low velocity than the straight pipe. And the straight pipe in the end will give a greater conductivity than the corrugated pipe. And without having any data on it I should assume that straight pipe at high velocities would have a greater conductivity than a curved pipe at high velocities.

The President: I would like to ask Mr. Richter if his ratios are good with different liquids, more viscous liquids for example?

Mr. Richter: The only point I am making is that with a hotter liquid the ratio still holds. The difference between heat and cold is a factor of three, as I remember in the case of water. We have not gone further with syrups or liquors of higher viscosity, but I feel that the ratios would probably hold.

Dr. Frerichs: The laws of heat conductivity are of great importance in the refrigerating industry, and I have run against some quite interesting problems in that industry. The efficiency of coolers or heat exchangers depends on the difference of temperature between two media. If the cooling water in pipe condensers runs through a large pipe, then the interior core of the water takes very little part, it would seem, in the exchange of heat. The efficiency of the cooler or the heat exchanger is very much increased if, during the passage of the cooling water, the water in the pipes is continually mixed, so that the average temperature of the outer film and the inner core is equalized. In this case the difference in temperature between the cooling medium and the material which is to be cooled, is a maximum. We experience in the refrigerating industry another phenomenon which is not exactly an interchange in temperatures between two liquids, but in which actual condensation of a vapor takes place. Double pipe condensers are used in the

condensation of ammonia gas to the liquid state. If you have for instance a condenser 10 or 12 pipes high, and if you admit the ammonia vapors into the top, running off the liquid ammonia at the bottom, then the cooler has a certain efficiency. If you reverse this flow, entering the ammonia vapors in the bottom of the condenser, and letting the condenser fill up with liquid ammonia, then the efficiency of the same number of pipes in the same cooler is about three-fold what it was before. In other words, if you have a double pipe condenser in which you condense ammonia gas, entering the ammonia vapors at the top and running off the liquid at the bottom, and having the condenser itself always empty of liquid, then this condenser has a certain efficiency. If you reverse this, entering the compressed ammonia gas near the bottom, letting the double pipe condenser fill up with liquid ammonia, forcing the ammonia gas which is to be liquefied through this liquid ammonia, and leading the liquid ammonia off from the top of the condenser, then the efficiency of that condenser is about three-fold what it was the other way. In this manner a great many ice plants in the West have been remodeled with the result that the efficiency of the condensers is increased several times. Louis Block, a refrigerating engineer of St. Louis, who has done a great deal in this direction, is the originator of this invention.

Mr. Dodge: We are interested in cooling distillates in connection with coal tar products. The heat transfer is very much the same as in the refrigerating business. Formerly it was customary to use a coil in a tank for cooling, and in that case the central part of the tank which is not occupied by coils allows the water to short circuit. Much more water is used to condense a given volume of liquid than if the coils are placed in an annular tank with water only in the annular space. It is also true, and this paper points out the explanation, that the ordinary multiple tube condensers are not suitable to condense vapors and cool them, especially volatile vapors, so that they can be safely put away in tanks without loss of large quantities by evaporation. Some of the people who have built plants in the last few years have relied on multiple tube condensers to condense the vapors and cool the distillate. They have an arrangement whereby the bottom end of the tubes are submerged, the vapors being around the tubes, and the water flowing through them. This leads to fairly cold distillate when running slow. But immediately you get a normal speed of distilla-

tion it becomes warm and volatile vapors are lost. To counteract that in some cases we have had to add double tube pipe coolers at the end, to cool the distillate. They don't have sufficient travel in tubular condensers so that the distillate will become cooled to the water temperature. An annular tank with coils in it can be designed which will bring the distillate out within two or three degrees of the temperature of the cooled water.

The PRESIDENT: I don't just understand, Mr. Dodge, the advantage of the annular tank over a tank which is filled with water.

Mr. DODGE: The water goes in at the bottom and up the center, and does not give any velocity on the outside of the pipes.

Mr. RICHTER: We also found in actual practice with the annular type we can increase the conductivity by about 14 per cent over the plain type. But the annular type is only about one-half as efficient as the other type.

The PRESIDENT: Two of my own experiences with helical coolers may amuse you, if they don't instruct you. In 1884, I went with the Richmond Paper Company at a salary of $2 a day, as part chemist and part clerk. They were not sure whether I could earn the salary of chemist, but they thought I might perhaps fill it out as clerk, and I very soon found myself superintendent of their pulp mill for the reason that there was no one else that they could put forward in the first plant using this process in the country. They had built the coolers in the form of 60 feet 6 inch lead pipe in a helix in the tank. And it happened on frequent occasions that the sulphur-burner man would let the burners get too hot, and those pipes would fill up with sublimed sulphur. Then the lead burners would have to split the pipes at reasonable intervals and take out that sublimed sulphur, and seal up the pipes and start over again. We got over that by later installing a straight-tube arrangement very much on the type of the ordinary boiler. There were tubes opening from the connecting chambers at either end, and a perfectly straight passage through.

The other experience refers to the blow-off pipe from the digesters. At the end of the blow-off pipe we had 300 ft. of 3-in. bronze pipe in the tanks to heat the wash water. One day old Jim Marshall, superintendent of the whole plant, came in and wanted to know very profanely why I was blowing off so slowly. I said, "Because if we blow faster we will tip the strainer and choke up the pipes with pulp." He said, "Give her hell." Thereupon I

opened her up and got the pipes full, and we were not able to use the heater coil again for three months.

Dr. FRERICHS: The efficiency of double pipe condensers can be increased if the interior pipe is filled with iron borings or some material which obstructs the flow of the cooling medium. In this way you can increase the efficiency of a double pipe condenser, about two-fold. I ascribe this increase in efficiency to the better mixing of the cooling water, so that the inner core of the cooling water comes in contact with the surface to be cooled.

Dr. MOORE: Along the line of the remarks by Dr. Frerichs, I made a few experiments, but not enough to be talked of here. But if you take a piece of iron and twist it so as to make it go around encircling the inside of your pipes, so that you have a screw going through there, you will increase your conductivity immensely by that means. Haven't you done some work on that line, Mr. Howard, too?

Mr. HOWARD: We have a cooling proposition at one of our works, where we want to use fresh water for the cooling medium, but we have a limited supply of fresh water and an unlimited supply of salt water. Therefore it was necessary to arrange an interchanger. For this purpose a multiple tubular cooler or heat interchanger with straight-tubes was used. Later the capacity of this interchanger was increased three-fold by inserting a spiral in last tube.

Mr. GRAHAM: Mr. Chairman, I know of some work which has been done with concentric annular rings, and the medium was put through there at high velocity. It is what is called by the inventor a jolt tube, which jolts the film to the surface. He claims to have obtained about three times the conductivity of the straight tube.

Mr. RICHTER: There is one factor which a man must not neglect if power is of importance. We succeeded in increasing the conductivity by a single pipe, three-fold. We also found that the change in the method increased our power factor by 3. Now, whenever power is of importance, that must not be neglected.

Mr. ZEISBERG: Mr. Chairman, I would like to ask Mr. Richter one question not made clear in his paper, and that is whether anything is needed to support the inner tube so that it would be at a great distance from the outer tube. In winding two tubes into spirals you will give a different bed of the inner tube against the

outer tube than where one is nearly straight. That may account for some difference in efficiency.

Mr. RICHTER: In fabricating the helical type it was made in sections one-third the circumference of a circle. We tried at first putting beads at intervals of three feet along the tube, but discarded the method inasmuch as in the entire cooler there were about 12 such beads and each bead was about a quarter of an inch, so that it was really negligible. I believe that the inner tube was well distanced all around, due to the fact that it was made up in sections.

Mr. DODGE: There was one other thing which I wished to mention but failed to. That in arranging worms it has been customary for us to build beginning at the top with a large size and reducing the size of pipe as the vapors become condensed.

Mr. HOWARD: Mr. Chairman, it seems to me that it is interesting to speculate on why the helical form is more efficient than the straight tube. There are two explanations which occur to me at the moment. One is that the current inside of the inner tube, through continually changing its direction, produces a sort of scouring effect against the outside of the helix. There is also another cause that might increase the efficiency of the inside of the helix. As the water or the liquid in contact with the inside curve of the helix becomes colder, and therefore heavier, it would be acted upon more strongly by centrifugal force which would tend to pull it away from the inner wall of the helix and throw it toward the hotter and consequently less dense solution in the middle of the pipe forcing the hotter solution to go back in its place. It is possible that the increased efficiency of the curved pipe for heat transference is due to both of these causes.

There is room for more investigation of this problem. It would be interesting to compare pipes bent to different radii. The natural assumption would be that the shorter the radius of the helix the greater its efficiency as a heat transferrer per unit of surface, but the more power required to maintain rapid circulation. It would also be interesting to compare the efficiency of this type of heat transferrer with a straight pipe having a spiral inside.

Dr. FRERICHS: In 1892 I remodeled my ammonia works. At that time I constructed vertical double pipe condensers which were used for 18 years. I made those condensers on a double pipe type, but took a 16-inch pipe and a 14-inch pipe, one within the other, leaving an annular space between the two pipes which measured

half an inch or three-quarters of an inch. The cooling water was on the inside of the 14-inch pipe which was closed at the top. I had two kinds of those condensers, one with a spiral rod wound around the inside pipe, and filling up the annular space, forcing the vapors which were to be condensed to travel in a spiral way around the inside pipe on its way down—and I found these coolers in which spiral travel was enforced, to be much more efficient than other coolers which did not have such a spiral arrangement.

Mr. LAIB: I think the gentleman has overlooked the fact that in the same lineal distance of pipe in the case of helical or spiral pipe a greater cooling area is exposed, which would account for a greater degree of cooling, which might have been obtained by increasing the length of straight pipe, or adding more coils.

Dr. MOORE: That I think is negligible. That has been considered, but when you consider even allowing the maximum which you possibly could consider, it in no way accounts for the great discrepancy. It might account for two or three per cent of it, but will not anywhere near account for the difference of 50 per cent. It would not affect more than 2 per cent of the entire difference of 50 per cent.

ACCIDENT PREVENTION IN THE MILL

By HUGH K. MOORE

Read at the Savannah Meeting, Dec. 3, 1919

I have been asked to address you for a period of not over twenty minutes on a subject so long that it would fill a fairly good-sized library.

The subject so glibly asked for is "The Prevention of Accidents in Mills and Mines." One cannot scratch the surface of such a subject in the time given, so I shall neglect the mines entirely and touch on only a few of the major principles and their results. As such it cannot be of interest to those who have gone into the subject but I hope this will interest some of those who have not gone into it.

Do you know that in the United States even now in spite of the great progress which has been made in the prevention of accidents, that there are 35,000 lives lost annually? That there are 350,000 serious accidents such as dismemberments, etc., and that there are 2,000,000 minor accidents causing loss of time? There is also paid out $500,000,000 annually for accidents.

The above does not include occupational disease in which the workers are wholly or partially incapacitated and which often results in death. Let us make a rough approximation as to what this means in economic loss.

If we figure the economic loss of a man as 9000 working days (see Table 2) we have from 35,000 lives 315,000,000 working days and if we figure $3.00 a day based on present standard of wages, we have an annual loss in lives of approximately $945,000,000. To obtain an approximation of the loss for the 350,000 dismemberments, is much more difficult as we do not know the percentage of each.

Table 1 gives the comparative time allowances for specified disabilities under the laws of various states—other disabilities compared with loss of arm.

TABLE 1

Weeks for which Compensation is Payable

Loss of=

States.	Arm.	Hand.	Leg.	Foot.	Eye.	Thumb.	One Joint of Thumb.	1st Finger.	2d Finger.	3d Finger.	4th Finger.	Great Toe.
Connecticut [1]	208	156	182	130	104	38	19	38	30	25	20	38
Illinois [2]	200	150	175	125	100	60	30	35	30	20	15	30
Indiana [1]	200	150	175	125	100	60	15	30	30	30	30	30
Iowa [1]	200	150	175	125	100	40	20	30	25	20	15	25
Kentucky [1]	200	150	200	125	100	60	30	45	30	20	15	30
Maine [3]	150	125	150	125	100	50	25	30	25	18	15	25
Maryland [1]	200	150	175	150	100	50	25	30	25	20	15	25
Massachusetts [2]	50	50	50	50	50	12	12	12	12	12	12	12
Michigan	200	150	175	125	100	60	30	35	30	20	15	30
Minnesota [1]	200	150	175	125	100	60	30	35	30	20	15	30
Montana [1]	200	150	180	125	100	30	20	20	15	12	9	15
Nevada [2]	217	173	195	152	108	65	32½	39	30	22	17	30
New Jersey [2]	200	150	175	125	100	60	30	35	30	20	15	30
New York [1]	312	244	288	205	128	60	30	46	30	25	15	38
Ohio [2]	200	150	175	125	100	60	30	35	30	20	15	30
Oklahoma [1]	250	200	175	150	100	60	30	35	30	20	15	30
Oregon [4]	416	329	381	277	173	104	52	69	39	35	26	43
Pennsylvania [1]	215	175	215	150	125	..	..	..	..	..	..	..
Vermont [1]	170	140	170	120	100	40	20	25	20	15	10	20
Wisconsin [1]	240	160	160	120	120	40	20	20	15	8	10	20

[1] Payments under this schedule are exclusive or in lieu of all other payments.
[2] Payments under this schedule are in addition to payments on account of temporary total disability.
[3] Payments cover total disability. Partial disability may be compensated at end of periods given for not over 300 weeks in all.
[4] For this State the periods named are not to be reduced by any time for which payments on account of temporary disability have been made.

TABLE 1—*Continued*

RELATIVE TIME ALLOWANCE (LOSS OF ARM = 100)

Loss of =

States.	Arm.	Hand.	Leg.	Foot.	Eye.	Thumb.	One Joint of Thumb.	1st Finger.	2d Finger.	3d Finger.	4th Finger.	Great Toe.
Connecticut	100	75	88	63	50	18	9	18	14	12	10	18
Illinois	100	75	88	63	50	30	15	18	15	10	8	15
Indiana	100	75	88	63	50	30	8	15	15	15	15	15
Iowa	100	75	88	63	50	20	10	15	13	10	8	13
Kentucky	100	75	100	63	50	30	15	23	15	10	8	15
Maine	100	83	100	83	67	33	17	20	17	12	10	17
Maryland	100	75	88	75	50	25	13	15	13	10	8	13
Massachusetts	100	100	100	100	100	24	24	24	24	24	24	24
Michigan	100	75	88	63	50	30	15	18	15	10	8	15
Minnesota	100	75	88	63	50	30	15	18	15	10	8	15
Montana	100	75	90	63	50	15	10	10	8	6	5	8
Nevada	100	80	90	70	50	30	15	18	14	10	8	14
New Jersey	100	75	88	63	50	30	15	18	15	10	8	15
New York	100	78	92	66	41	19	10	15	10	8	5	12
Ohio	100	75	88	63	50	30	15	18	10	10	8	15
Oklahoma	100	80	70	60	40	24	12	14	12	8	6	12
Oregon	100	79	92	67	42	25	13	17	9	8	6	10
Pennslyvania	100	81	100	70	58	..	..	..	..	..	..	..
Vermont	100	82	100	71	59	24	12	15	12	9	6	12
Wisconsin	100	67	67	50	50	17	8	8	6	3	4	8

Taken from U. S. Department of Labor, Bureau of Labor Statictics, Bulletin 216–13.

Table 2 gives time losses fixed for death and permanent disabilities.

TABLE 2

TIME LOSSES FIXED FOR DEATH AND PERMANENT DISABILITIES

Items.	Time Losses in Days.	Per Cent. of Loss of Arm.	Per Cent of Permanent Total Disability.
Death	9,000	....	85.7
Permanent total disability	10,500	....	100.0
Loss of member:			
Arm	2,808	100.0	26.7
Leg	2,592	92.3	24.7
Hand	2,196	78.2	20.9
Foot	1,845	65.7	17.6
Eye	1,152	41.0	11.0
Thumb	540	19.2	5.1
One joint of thumb	270	9.6	2.6
First finger	414	14.7	3.9
Second finger	270	9.6	2.6
Third finger	225	8.0	2.1
Fourth finger	135	4.8	1.3
Great toe	342	12.2	3.3
One joint of great toe	171	6.1	1.6

Taken from U. S. Department of Labor, Bureau of Labor Statistics, Bulletin 216–13.

Averaging all but the first two items, in Table 2, we get an economic loss of 997 working days, which at $3.00 per day is an economic loss of $2991.00 per accident of the dismemberment class. We thus have an approximate economic loss from dismemberments of 350,000 people of the great sum of $1,046,850,000. Let us assume for a basis of minor accidents that the economic loss is 12 days' time, then we have 2,000,000 accidents, have an economic loss of 72,000,000.

Tabulating we have:

35,000 lives at $27,000	$945,000,000
35,000 dismemberments at $2991	1,047,000,000
Annual payments	500,000,000
2,000,000 minor accidents at $9.00	72,000,000
	$2,564,000,000

Here alone we have a tremendous economic loss of over two and a half billion dollars anually. If to this we add the losses due to total disability, the cost of doctors, nurses, medicines and occupational diseases, we shall have a total annual loss of over $3,000,000,000 a year. In addition to this great economic loss we have incalculable losses due to the suffering and provocation for which these accidents are the direct causes.

A few words of explanation of the above may not be out of order. Data obtainable show that the averages of ages of death of above is 30 years, and as a man's working life is 60 years, we thus find thirty years to be economic value sustained by his death. Using the above as a basis we find that this $27,000, the economic value of one worker's life, distributed over 30 years, is an equivalent of an economic loss of $900 per year for such a death, but as these accidents occur not only once in thirty years, but every year, we have to charge the full amount, viz., $27,000 for each year. In the way way we have to figure the average loss for dismemberment—viz., $2991 per man—is distributed over at least 30 years so that his actual loss of earning power is approximately $100 or less per year, but as these accidents also take place every year in the 30 years, we also charge the whole amount per year, viz., $2991.

As to the value of minor injuries, I have not been able to find any data for the whole country, but as a basis I am using some obtained from the Brown Company for the month of August, 1919, classifying as minor injuries all those in which the worker returned to work within a month. Of such accidents we had 21 in number with total time lost of 252 days. This gives an average of 12 lost days for each minor accident. As the hazards in a concern like the Brown Company are far less than those which occur in railroads, steel industries, machine shops, ship yards, foundries, construction, etc., I consider the above very conservative. I might add that the Brown Company is more representative of the total industry of the United States than one not knowing it would think. In this we average over 3000 employees. The kinds of work done are various. We have wood operations, paper mills, chemical mills, oil mill, machine shop, electrical shop, railroads, railroad repair shop, construction work, engineering work, hoisting, conveying and many other operations.

To reduce accident losses is perhaps the most important prob-

lem of the times and the manufacturer finds that he can no longer disregard these losses, but that he must give to the subject increasing thought, even to the extent of creating safety bureaus headed by the most capable men he can find who, of course, being capable men, can demand and command very large salaries. The passage by twenty-nine states of workmen's compensation laws and the certainty of passage in all the other states has given this subject a great stimulus.

It has been found during the last few years that, owing to changes in the Compensation Acts, that in some cases compensation insurance rates have been increased in spite of a reduction in the number of accidents in an industry, and this alone may mean that even though the manufacturer has improved his accident record and safeguarded his plant, he may pay more for his insurance than he did a few years ago. The following chart of a typical state, viz., that of Massachusetts, illustrates this very forcibly.

CHART I.

A man may have cut his accidents in 1919 to 50% of those in 1912 and yet be paying more than he did in 1912. Of late years the efforts to reduce accidents have been so many and so pronounced that there are now many organizations formed for this purpose. The leading manufacturers, leading insurance companies and the United States Department of Labor are taking active measures along this line. The National Safety Council has been formed for this purpose and its influence is tremendous. To promote research on accident prevention in the mill, I suggest that a study be made of the following conditions:

1. Hygienic Conditions.
2. Occupational Conditions.
3. Physiological Conditions.
4. Psychological Conditions.

Owing to the limited time at my disposal, I shall not attempt to touch upon the first, third or fourth conditions but shall confine myself to a few remarks on the second item.

The first essential necessary to the reduction of accidents is Safety Education. This must start with the chief executive. The chief executive must supply the initiative for if he treats accident

prevention in a light, trivial manner, just so will the superintendents, foremen, assistant foremen and workmen treat accident prevention in the same trivial manner.

This step in the right direction having been taken, a campaign of education should be started among the foremen. Each must be taught that an accident is a very serious matter, and that for every such accident, he has lessened the earning power of his department, and consequently the earning power of the mill, which means that his own value to the mill is lessened. That he is morally responsible should be hammered into him on ethical and humanitarian grounds. If at the same time he is convinced that he is a

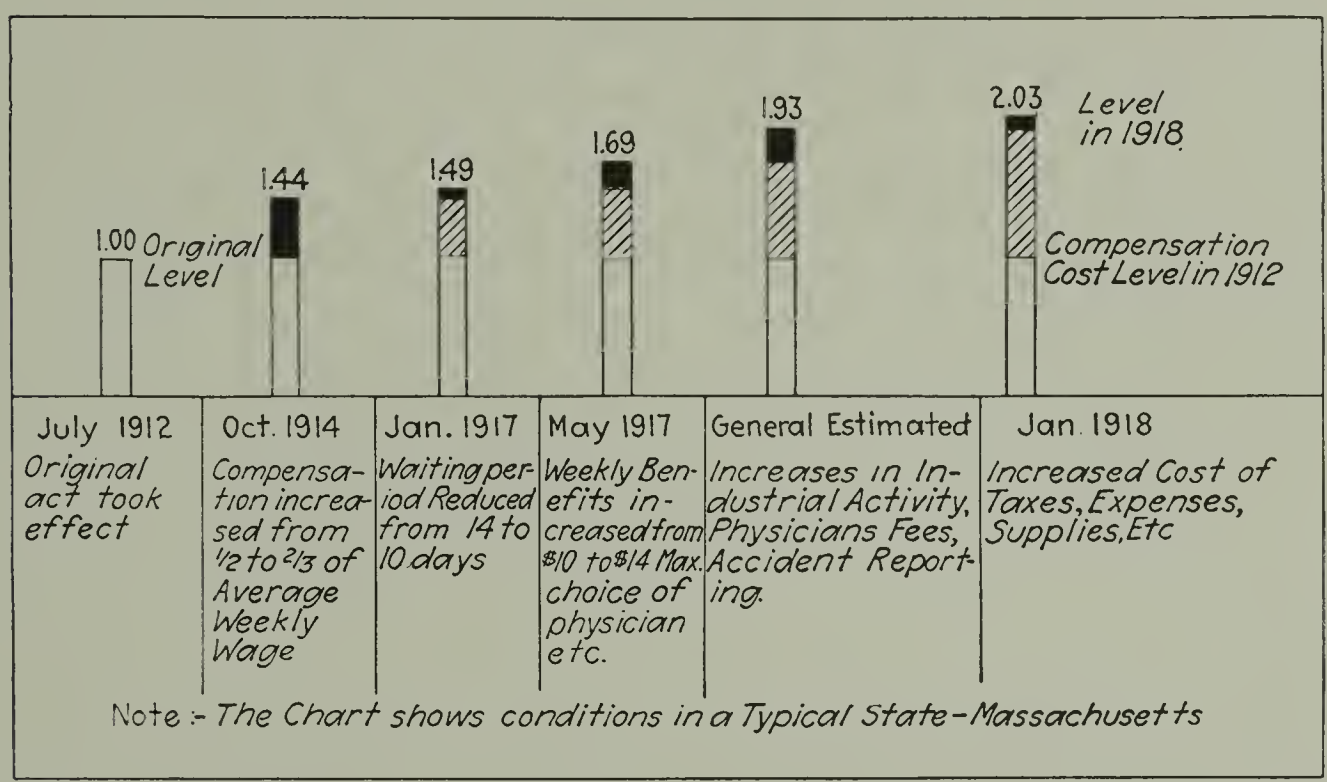


CHART 1.—Accident Prevention More Important every Year on Account of Increasing Cost of Workmen's Compensation.

bad business risk to his employer, it may be that the added incentive of self-preservation will make him more assiduous in carrying out the above moral obligations. And lastly, every employee must be educated to the fact that he is morally and personally responsible for every accident that he could have prevented. He must be made to understand that he has his part in the great accident prevention machine and that he must do his full duty if the machine is to run smoothly and properly.

I wish to call attention to the fact that no safety organization can function properly unless the management gives its full support and personal interest. Any safety movement of a sporadic nature

is not a success. Not until Safety First is drilled into all concerned, from employer to employee, to that extent that it is considered as fundamental a part of manufacture, as is the production, can any organization for safety expect to do its full duty and approach, to some extent, the goal which may be reasonably expected of it.

For those who have not made a study of this matter, I shall give here a skeleton of the Safety Organization in one department of the Brown Company, Berlin, N. H. Every department has its organization. They differ to a certain extent, each being so constituted as to give the best results under the conditions existing. In giving this I do not intend to convey the impression that the Brown Company is doing anything unusual, for such is not the case, as there are many concerns, which having started earlier, have developed the Safety Department to a far greater extent than we have.

The department organization alluded to above consists of a Medical Corps, Executive Committee and Working Committee. The Medical Corps consists of three doctors and a corps of district nurses. The doctors and nurses are called for all accidents of a serious nature and they tend out on the patient until the danger has passed.

The Executive Committee consists of all the heads of the component departments and each head appoints one man from his department to act with the working committee for four weeks, when a new representative is appointed. The Executive Committee meets every four weeks and acts on the recommendations of the working committee. At this meeting of the Executive Committee these suggestions and recommendations are assigned to their respective departments with orders that they be put in force. At the next meeting, each department head reports what has been done and results obtained from the same.

The working committee goes from place to place seeking causes for accidents or conditions which might make accidents possible. They make a special note of the conditions pointed out by the member of the committee, who is along with them. They are open to all suggestions which their presence may invite from the men at the time. I shall not attempt here even to list the various subjects of special attention such as stairways, platforms, etc.

We have established a First Aid Room with an up-to-date outfit, and this is regularly insepected by the District Nurse.

All accidents of whatever magnitude are reported to the time office and a form is made out containing an accurate account of cause of accident, nature of same, and the names of the witnesses. Injuries of a minor nature are given First Aid treatment at the time office. If the case is serious, the services of the Medical Corps are requisitioned. The accident reports are placed in the hands of the Insurance Department, who investigate all details and record them for future reference. Of course, each report is also a warning to prevent future like accidents. We conduct an education campaign through every department of the mill and this is a feature the importance of which it is almost impossible to overestimate.

The above, owing to lack of time, is a very meager skeleton and can only be considered as an index finger pointing out a few steps on the way.

Undoubtedly the most essential feature of an Accident Reduction Policy is to educate the workman and the question naturally arises as to how this can be done or even if it can be done.

We already know that it can be done in part. The magnitude of this will depend upon the ingenuity of the educator and the acceleration given by the management.

The first step in the process of education is to have the engineer go through the mill room by room and occupation by occupation and study every operation and install improvements and safety devices where they are needed. As an example of the variety of things on which he may report I give a few out of the thousands which could be mentioned. Slippery floors, belt guards, gas masks, grounding static electricity belts where the air contains inflammable dust, finger protectors, eye protectors, dust removers, safe guards for prevention of burns, proper clothes, excessive fatigue and ten thousand other devices too numerous to mention here. Charts 2 and 3 show the effect of new labor overturn in the mill. While Charts 2 and 3 purport to show the record of the Sulphite Mill of the Brown Company, they must only be taken as an indication of tendencies. Prior to April, 1914, our records are exceedingly incomplete and only the serious accidents were reported. Even though this was so, the accidents shown number approximately 15 per thousand men employed. In April, 1914, we had our first Safety Meeting with the result that during 1915 and 1916

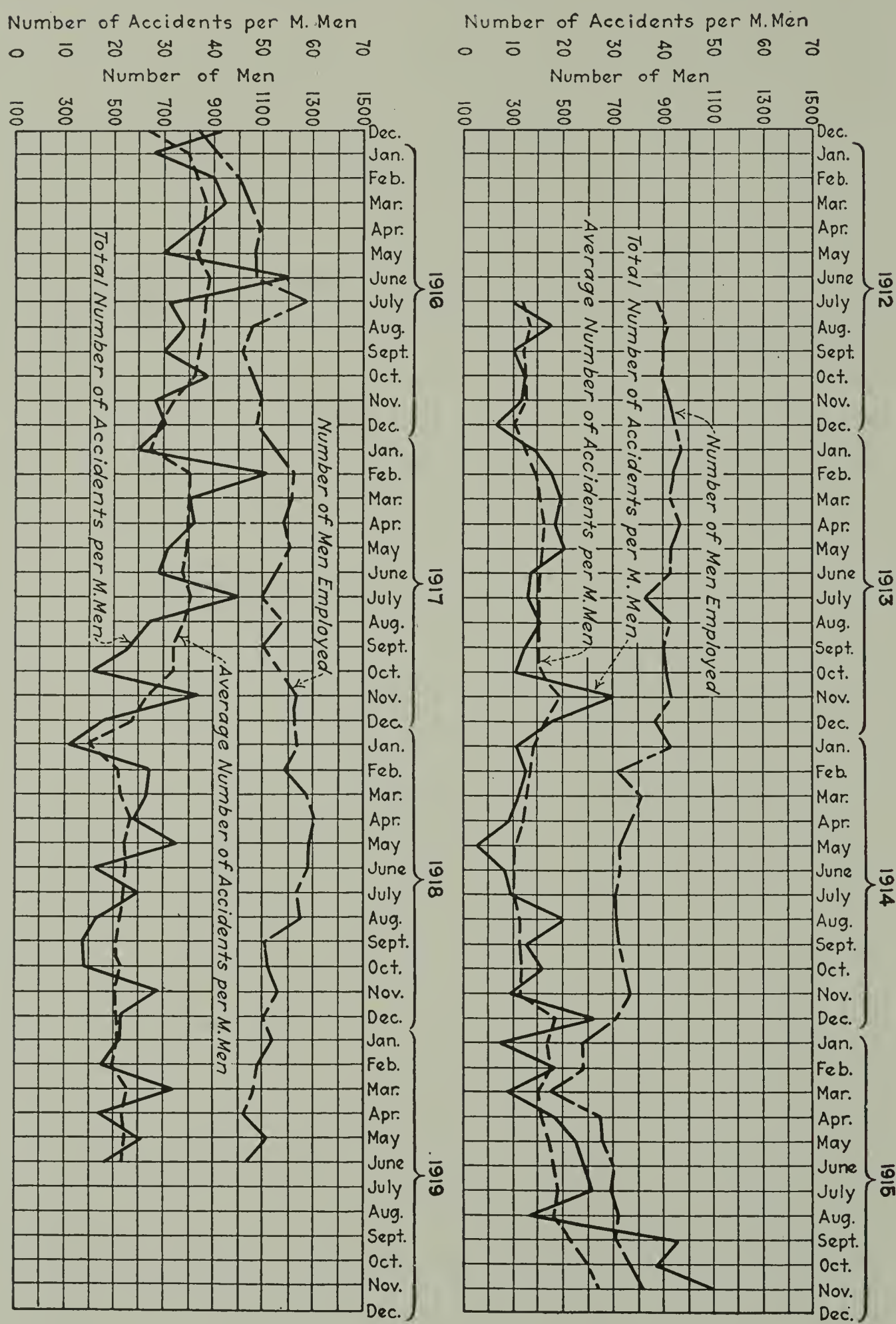


CHART 2.—Showing Effect of Labor Overturn on Accident Rate, Sulphite Mill, Brown Co., Berlin, N. Y.

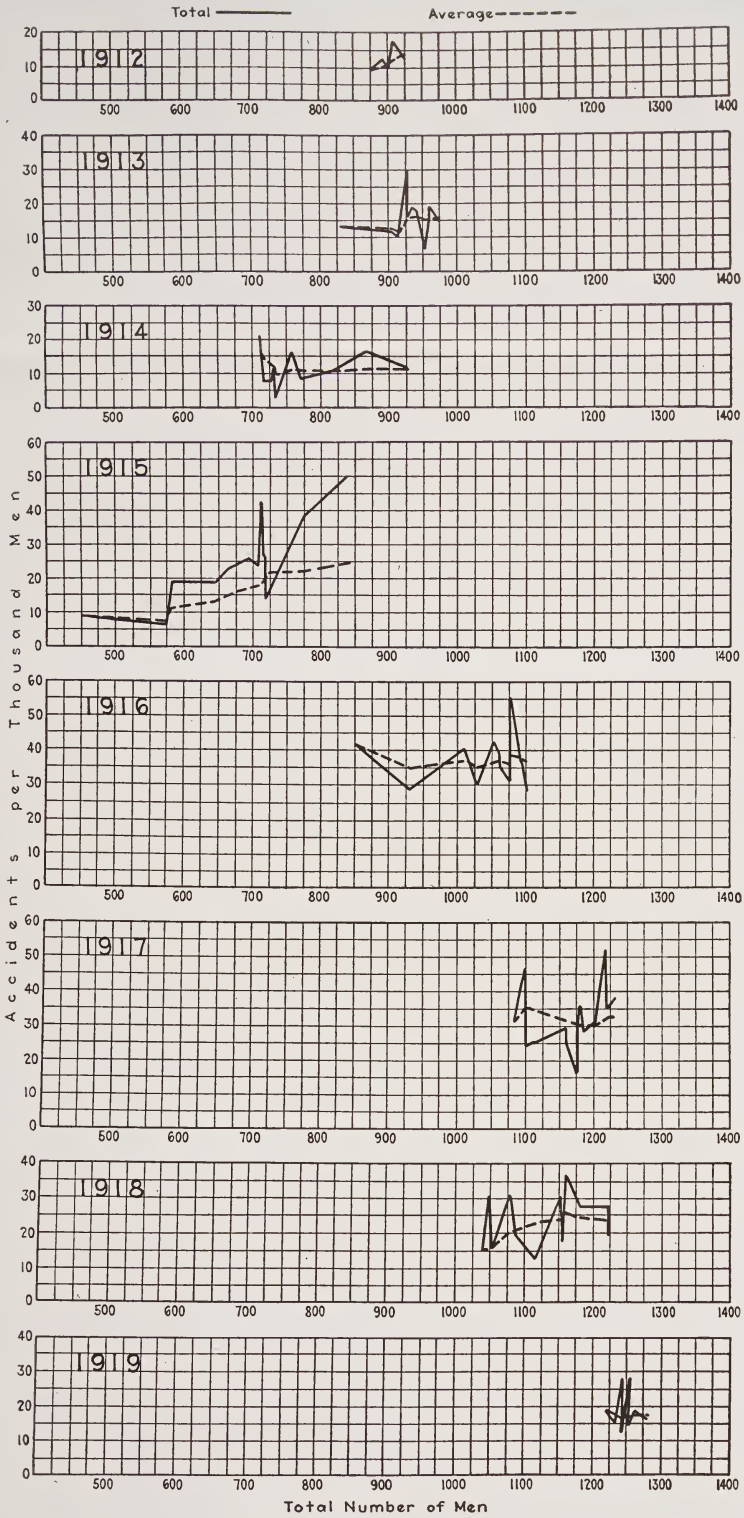


CHART 3.—Showing Effect of Labor Overturn on Accident Rate. Brown Company, Sulphite Mill, Berlin, N. Y.

(*To face page 196.*)

every accident was reported no matter how slight and there were many cases purporting to be accidents which upon investigation proved not to be accidents at all in the mill. This accounts for the sudden rise in accidents per thousand in 1915 and 1916. It will be noticed in this chart that the number of accidents per thousand men employed increases with the number of men for years 1912, 1913, 1914 and 1915, and part of 1916.

The meaning of this is that when you have a greater number of men you necessarily have more new men and as the accidents are greater among the new men than those accustomed to their jobs, we consequently have the above correlation. This is brought out more clearly if we study Chart 3, which shows the above facts more clearly than Chart 2. That the accidents per 1000 men do not rise in 1919 is due to the increasing activity of our safety committee. It will be seen from the above that the subject of overturn of labor in the mill must be studied when analyzing accident results. While the records from which the above charts are taken are neither complete nor exact for the years prior to 1919, they show general tendencies. In a few years I hope to have data from which we can figure more exactly what is the effect of overturn of labor upon the rate of accident in the mill.

The very installation of all these things will yield not only large dividends to the management and employees by the reduction of accidents and suffering caused thereby, but it will yield actual monetary dividends by the reduction of payments required by the Workmen's Compensation Act.

It will also yield dividends by having less disorganization of the personnel of the plant. When the operatives observe this large expenditure of money by their employers, they know that the management is taking hold of this matter seriously. In addition to the above this will also act as one of the means of preventing overturn of labor in the mill. New men are a most prolific source of accidents and any great influx of new men will boost the accident record.

Our curves show that in spite of our increased activities in prevention of accidents that an influx of new men is always accompanied by an increase in our accident rate. Labor experts have shown that it costs from $10 to $300 according to occupation for the overturn of one man. It will readily be seen that a serious accident must necessarily mean the overturn of at least one man.

Actually it means much more for men will not remain where accidents are prevalent.

The prevention of accidents and reduction of overturn of labor are mutually interdependent as the first makes for the second and the second makes for the first.

The next step is to highly educate all the foremen not only as to causes of accidents but as to First Aid and like accessories.

Simultaneously with the above typical posters should be placed in every time office and every conspicuous place around mill and town so that the men are constantly reminded of the seriousness of neglect and carelessness. In order for these to serve their full purpose they must be changed at least once a month and I believe once in two weeks would be better.

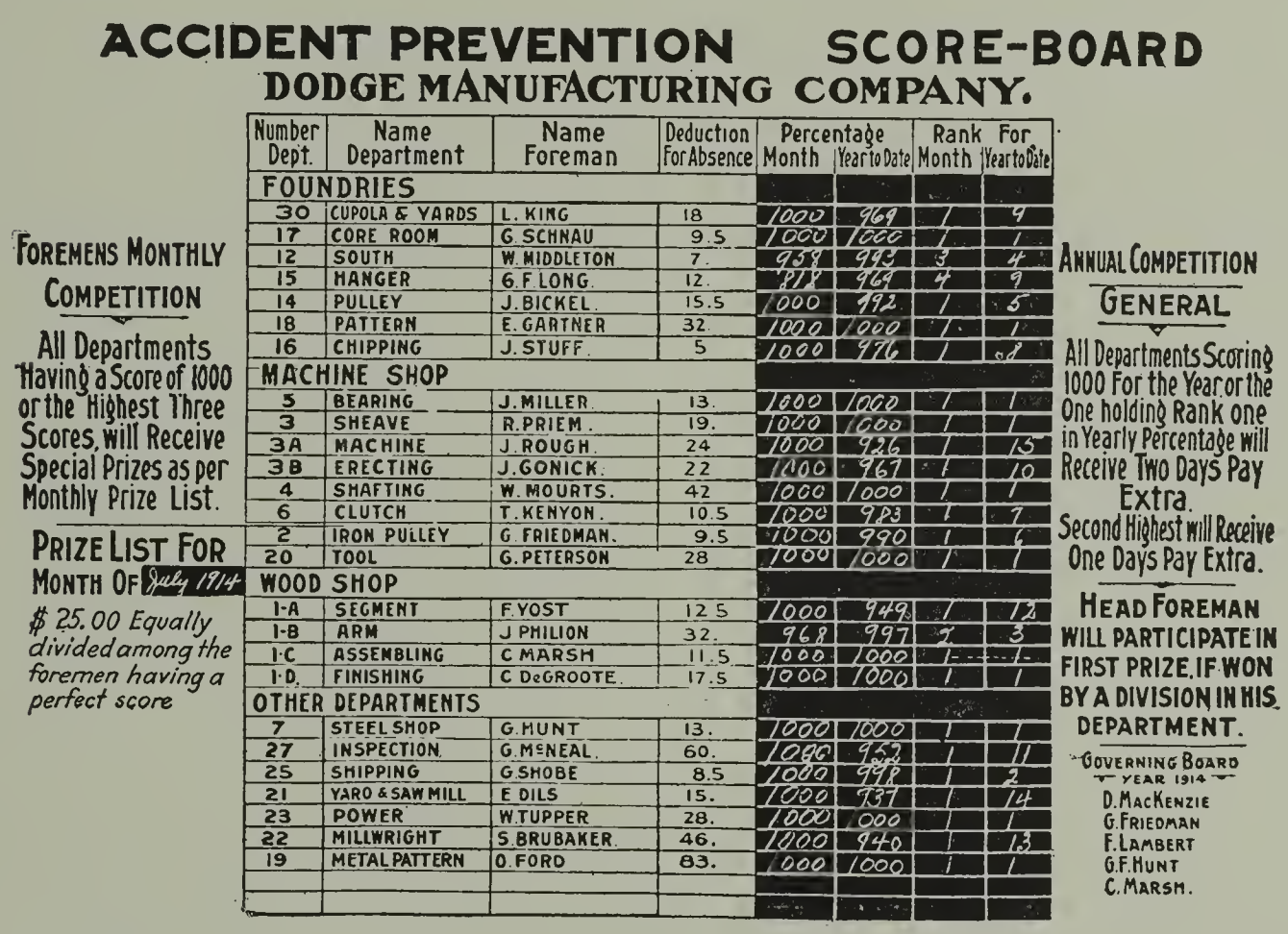
Not only this but the education should extend to the schools. The children should be given first aid lessons and talks on the penalties paid by carelessness. The campaign of education should be carried still further. A day should be set apart in which all the churches should devote a service to Sin or Carelessness, Forgetfulness, Inattention, etc., and finally inasmuch as the moving picture show is now a powerful force in education, moving pictures should be given illustrating the crop of accidents growing from the seeds of carelesness.

The Liberty Mutual Insurance Company has a very fine film, "The Outlaw," illustrating the above. I presume there are many such films, and when they are catalogued so that the manufacturer can know where they can be obtained one very important step will have been taken.

Another important step in the education of the employees is to create a desire to make a record. One method which has been tried out very successfully by the Dodge Mfg. Company is to promote friendly rivalry among the foremen by contrasting their efficiencies on a score board. Of course the score must be so computed that the foreman who has a small number of employees shall not be at a serious disadvantage with the foreman who has a large number of employees. The friendly rivalry is of great value and woe betide the careless workman who causes his team to lose by his indifference. To obtain a score of 1000 is some achievement.

Chart 4

Here is a photograph of the score-board used by the Dodge Mfg. Company. In some cases a monetary reward is given to the foreman having the best score for the month. The yearly score is based on the monthly scores. This is necessary in order to keep up interest in the movement by always having the possibility of a foreman improving his record in a succeeding month with the



ACCIDENT PREVENTION SCORE-BOARD
DODGE MANUFACTURING COMPANY.

Number Dept.	Name Department	Name Foreman	Deduction For Absence	Percentage Month	Percentage Year to Date	Rank For Month	Rank For Year to Date
FOUNDRIES							
30	CUPOLA & YARDS	L. KING	18	1000	969	1	9
17	CORE ROOM	G. SCHNAU	9.5	1000	1000	1	1
12	SOUTH	W. MIDDLETON	7.	958	993	3	4
15	HANGER	G. F. LONG.	12.	918	969	4	9
14	PULLEY	J. BICKEL.	15.5	1000	992	1	5
18	PATTERN	E. GARTNER	32.	1000	1000	1	1
16	CHIPPING	J. STUFF.	5	1000	976	1	8
MACHINE SHOP							
5	BEARING	J. MILLER.	13.	1000	1000	1	1
3	SHEAVE	R. PRIEM.	19.	1000	1000	1	1
3A	MACHINE	J. ROUGH.	24	1000	926	1	15
3B	ERECTING	J. GONICK.	22	1000	967	1	10
4	SHAFTING	W. MOURTS.	42	1000	1000	1	1
6	CLUTCH	T. KENYON.	10.5	1000	983	1	7
2	IRON PULLEY	G. FRIEDMAN.	9.5	1000	990	1	6
20	TOOL	G. PETERSON	28	1000	1000	1	1
WOOD SHOP							
1-A	SEGMENT	F. YOST	12.5	1000	949	1	12
1-B	ARM	J. PHILION	32.	968	997	2	3
1-C	ASSEMBLING	C. MARSH	11.5	1000	1000	1	1
1-D	FINISHING	C. DeGROOTE.	17.5	1000	1000	1	1
OTHER DEPARTMENTS							
7	STEEL SHOP	G. HUNT	13.	1000	1000	1	1
27	INSPECTION	G. McNEAL.	60.	1000	952	1	11
25	SHIPPING	G. SHOBE	8.5	1000	998	1	2
21	YARD & SAW MILL	E. DILS	15.	1000	937	1	14
23	POWER	W. TUPPER	28.	1000	000	1	1
22	MILLWRIGHT	S. BRUBAKER.	46.	1000	940	1	13
19	METAL PATTERN	O. FORD	83.	1000	1000	1	1

FOREMENS MONTHLY COMPETITION

All Departments Having a Score of 1000 or the Highest Three Scores, will Receive Special Prizes as per Monthly Prize List.

PRIZE LIST FOR MONTH OF July 1914

$ 25.00 Equally divided among the foremen having a perfect score

ANNUAL COMPETITION

GENERAL

All Departments Scoring 1000 For the Year or the One holding Rank one in Yearly Percentage will Receive Two Days Pay Extra.

Second Highest will Receive One Days Pay Extra.

HEAD FOREMAN WILL PARTICIPATE IN FIRST PRIZE, IF WON BY A DIVISION IN HIS DEPARTMENT.

GOVERNING BOARD
YEAR 1914
D. MACKENZIE
G. FRIEDMAN
F. LAMBERT
G. F. HUNT
C. MARSH.

Chart 4.—Accident Prevention Score-Board, Dodge Manufacturing Co.

chance that something may go amiss in the department which had the high score the preceding month.

The Dodge Mfg. Company has developed this phase of the subject to such an extent that in 26 departments, 5 departments had perfect scores for a period of two years. In the Brown Company we have used the following method with success.

Realizing the necessity of having the employees consider the prevention of serious accidents we established in addition to the usual accident and insurance compensations an association known as the Brown Company Relief Association. Every employee of the Brown Company is eligible to join and about 90% of the

employees belong to this. Every man pays 1/20 of his weekly wages based on a six-day week once every 4 weeks, and at the end of a period of 3 months the unexpended balance is paid back to the men in form of dividends. These average in the vicinity of 65% of their payments. The money so contributed insures the men not only against accidents which occur in the mill but against accidents and sickness which occurs outside of the mill. The Brown Relief Association thus insures every man against loss of time

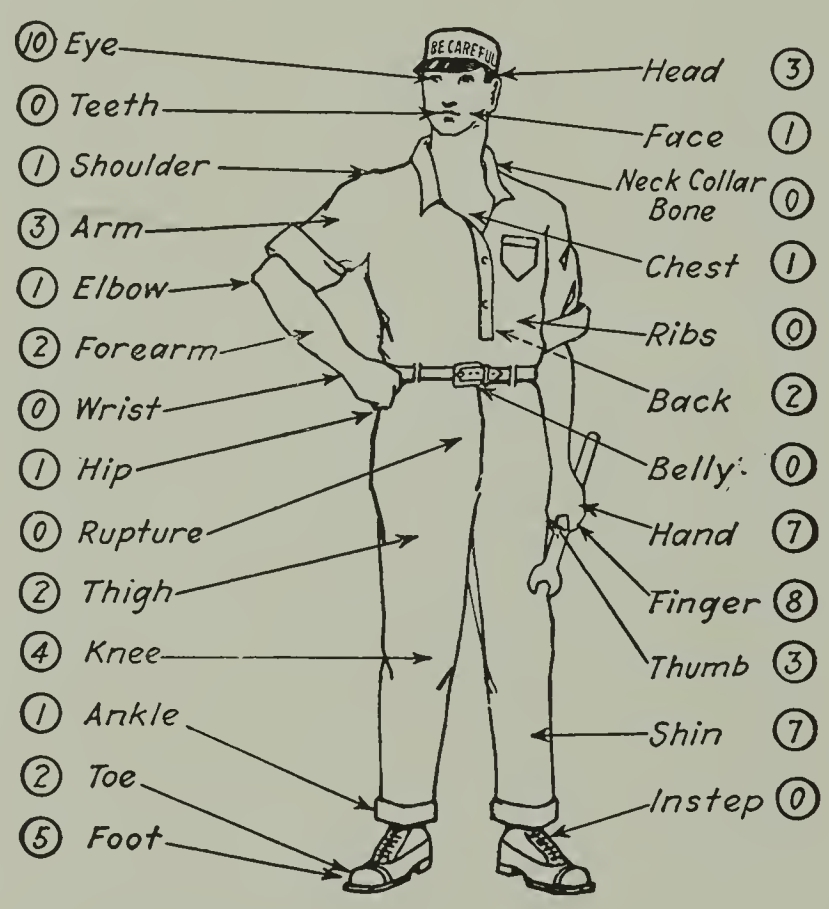


CHART 5.—Total Injuries=64.—Brown Company, Berlin, N. Y.

from almost every recognized cause. It is officered by its own men and employs its own doctors and lawyers. The Brown Company pays half of the benefits. The repayments of dividends is an important factor in this scheme as it induces every man to become his brother's keeper due to the fact that his dividends can only be increased by the prevention of accidents and frauds.

We believe that this Relief Association gives greater protection than any insurance company known to us. We also believe that

it is at the same time the cheapest insurance in the country to-day.

I should like to deal with this phase of the subject more at length, but must pass on.

An analysis of different causes of accidents will be of great interest not only to the novice in this kind of work but to many of those who have been engaged in such work for years.

TABLE 3

TABLE OF BODILY INJURIES, BROWN COMPANY, BERLIN, N. H.

(See Chart 5)

Month of August, 1919

Locality.	No.	Per Cent.	Locality.	No.	Per Cent.
Eye	10	15.6	Forearm	2	3.1
Fingers	8	12.5	Toe	2	3.1
Hand	7	10.9	Hip	1	1.5
Shin	7	10.9	Elbow	1	1.5
Foot	5	7.8	Ankle	1	1.5
Knee	4	6.2	Shoulder	1	1.5
Head	3	4.7	Face	1	1.5
Thumb	3	4.7	Chest	1	1.5
Arm	3	4.7	Ribs	0	0.0
Back	2	3.1	Collar bone	0	0.0
Thigh	2	3.1	Belly	0	0.0
			Wrist	0	0.0
	54	84.2	Rupture	0	0.0
Total No.	64		Teeth	0	0.0
Per cent	99.4				
				10	15.2

It will be noticed from this chart that the greater per cent of injuries are in the extremities. This chart can be used successfully in each department to let the men visualize the accident record on the principle that many men will read cartoons or pictures when they will not take trouble to read the same facts in print.

Inasmuch as the nature and number of accidents vary in different industries, each plant should tabulate its accidents not only by mills but by departments in the mills. By so doing they not only obtain information as to which departments are the most hazardous but attention is focused on these departments, with the result that more study will be given to prevent accidents. In order to

TABLE 4

ACCIDENTS IN MILL A

Month of	Wood Room.	Barker Mill.*	Boiler House.	Paper.	Finishing Room.	Rewinders.	Beater Room.	Sulphite Mill.	Maintenance.	Yard.	Kraft to Beaters.	Elect. Repair (Opr.).	Cutters.	Machine Shop.	Blacksmith Shop.	Screens.	Total.
Approx. number of men....	70	16	55	106	37	9	86	130	112	98	64	64	21	11	3	10	...
December, 1918.....	2	1	1	4	0	2	2	1	1	1	0	0	0	0	0	0	15
January, 1919.....	0	0	0	3	0	0	1	1	1	0	2	0	0	0	0	0	8
February, 1919.....	1	0	0	4	0	0	0	1	1	0	0	1	1	0	0	0	9
March, 1919.....	1	0	0	0	1	1	2	0	5	2	0	1	0	0	0	0	13
April, 1919.....	2	0	0	0	0	0	1	1	1	3	0	1	0	1	1	0	11
May, 1919.....	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	1	4
June, 1919.....	0	0	1	0	0	1	0	0	0	1	0	1	0	0	0	0	4
July, 1919.....	0	0	1	0	0	0	1	0	0	4	0	1	0	0	0	0	7
Average.....	.75	.125	.375	1.3	.125	.5	.875	.625	1.25	1.5	.25	.625	.125	.125	.125	.125	8.875
	.875																

* Wood room and barker room in Mill A corresponds to the wood room in Mill B, so that these should be added together to get the equivalent in wood room of Mill B.

TABLE 4—*Continued*

ACCIDENTS IN MILL B

Month of	Machine Room.	Wood Room.*	Log Pond.	Steam Turbine.	Screen Room.	Elect. Dept.	Maintenance.*	Lunch Room.	Acid.	Yard.	Heine Boilers.	Bleachery.	Waste Liquor.	Steam.	Engines and Ref.	Total.
Approximate number of men	320	241	9	3	46	37	289	4	21	70	22	19	3	28	14	..
December, 1918	8	8	1	1	1	2	2	0	0	0	0	0	0	0	0	23
January, 1919	4	11	0	0	1	0	3	2	0	0	0	0	0	0	0	21
February, 1919	1	5	0	0	0	1	8	0	2	1	0	0	0	0	0	18
March, 1919	4	10	0	0	0	1	10	0	2	5	1	1	1	0	0	35
April, 1919	4	4	0	0	0	0	5	0	0	1	0	0	0	1	0	15
May, 1919	8	5	0	0	0	3	3	0	0	1	1	1	0	0	1	23
June, 1919	3	5	0	0	1	0	7	0	0	2	0	0	0	1	0	19
July, 1919	10	7	0	0	0	0	15	0	1	1	0	0	0	0	0	34
Average	5.25	6.875	.125	.125	.375	.875	6.625	.25	.625	1.375	.25	.25	.125	.25	.125	23.5
	6.062															

* Wood room and barker room in Mill A corresponds to the wood room in Mill B, so that these should be added together to get the equivalent in wood room of Mill B.

TABLE 5

Mill A

Accidents per Thousand in Department

Month of	Wood Room.	Barker Mill.	Boiler House.	Paper.	Finishing Room.	Rewinders.	Beater Room.	Sulphite Mill.	Maintenance.*	Yard.	Kraft to Beaters.	Elect. Repair (Opr.).	Cutters.	Machine Shop.	Blacksmith Shop.	Screens.
Approximate number of men	70	16	55	106	37	9	86	130	112	98	64	64	21	11	3	10
December, 1918	29	62.5	18.2	35.4	0	222	23.0	7.7	8.9	10.3	0	0	0	0	0	0
January, 1919	0	0	0	26.5	0	0	11.5	7.7	8.9	0	31.2	0	0	0	0	0
February, 1919	14.5	0	0	35.4	0	0	0	7.7	8.9	0	0	15.6	47.5	0	0	0
March, 1919	14.5	0	0	0	27.0	111	23.0	0	44.5	20.6	0	15.6	0	0	0	0
April, 1919	29.0	0	0	0	0	0	11.5	7.7	8.9	30.9	0	15.6	0	90.9	333.3	0
May, 1919	0	0	0	0	0	0	0	7.7	8.9	10.3	0	0	0	0	0	100
June, 1919	0	0	18.2	0	0	111	0	0	0	10.3	0	15.6	0	0	0	0
July, 1919	0	0	18.2	0	0	0	11.5	0	0	41.2	0	15.6	0	0	0	0
Average	10.8	7.8	6.8	12.2	3.37	55.5	10.6	4.8	11.1	15.3	3.9	9.75	5.9	11.3	41.6	12.5
		9.3														

TABLE 5—*Continued*

MILL B

ACCIDENTS PER THOUSAND IN DEPARTMENT

Month of	Machine Room.	Wood Room.*	Log Pond.	Steam Turbine.	Screen Room.	Elect. Dept.	Maintenance.	Lunch Room.	Acid.	Yard.	Heine Boilers.	Bleachery.	Waste Liquor.	Steam.	Engines and Ref.
Approximate number of men	320	241	9	3	46	37	289	4	21	70	22	19	3	28	14
December, 1918	25.2	33.9	111.0	333.3	21.7	54.0	6.94	0	0	0	0	0	0	0	0
January, 1919	12.6	42.4	0	0	21.7	0	10.4	500	0	0	0	0	0	0	0
February, 1919	3.1	21.2	0	0	0	27.0	27.8	0	95.3	14.3	0	0	0	0	0
March, 1919	12.6	42.4	0	0	0	27.0	34.7	0	95.3	71.5	45.5	55.5	333.3	0	0
April, 1919	12.6	17.0	0	0	0	0	17.3	0	0	14.3	0	0	0	35.7	0
May, 1919	25.2	21.2	0	0	0	81.0	10.4	0	0	14.3	45.4	55.5	0	0	71.4
June, 1919	9.4	21.2	0	0	21.7	0	24.3	0	0	28.6	0	0	0	35.7	0
July, 1919	31.2	29.6	0	0	0	0	52.1	0	47.6	14.3	0	0	0	0	0
Average	16.4	28.5	13.8	41.6	8.13	23.6	22.9	62.5	29.7	19.6	11.3	12.6	41.6	8.9	8.9

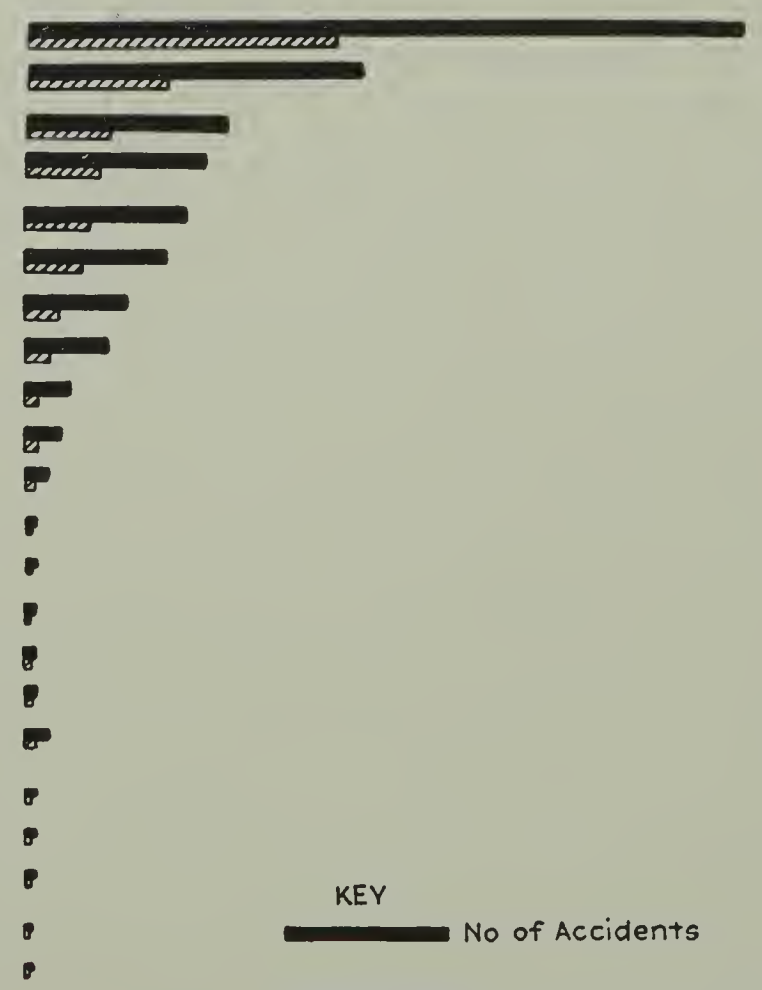
The above figures, owing to the shortness of time, are only indicative. It will be seen that where accidents happen in departments of only a few men, the accident figure per thousand is very high and of course is not correct as there might not another accident happen in these departments for years.

CHART 6

DISTRIBUTION OF ACCIDENTS IN CASCADE MILL OF BROWN COMPANY

YEAR, 1917

Accidents Caused by	No.	Per Cent.
Cut and bruised fingers	74	32.0
Slipping	35	15.0
Hit by loose material when it fell to floor	21	9.0
Moving material, crushed hands	19	8.0
Nails running in feet or scratching hands	17	7.0
Chips flying into eye	15	6.0
Bruised legs, caught between material, etc.	11	4.0
Falling from plank staging	9	3.0
Electric shock	5	2.0
Dropping axe on feet while putting handle in same	4	1.7
Overlifting, wrenched back	3	1.2
Overload, strained muscles	2	0.8
Run into by electric truck	2	0.8
Illness	2	0.8
Blood poison, sliver in hands	3	1.2
Chlorine spilled	1	0.4
Clothing caught in sprocket (killed)	1	0.4
Wagon overturning	1	0.4
Falling off team	1	0.4
Hot ashes	1	0.4
Run over by freight cars, no signal (killed)	1	0.4
Hole in floor	1	0.4
Climbing ladder, struck head on moving belt	none	



Hit by falling icicle	none		
Elevator accident	none		
Accidentally dropping material while carrying same, injuries to feet and legs	none		
Climbing ladder, struck head on bolt	none		
Burns received from tar	none		
Wrenched arm when stretching felt	none		
Putting on belt with stick while machinery was running	none		
Arm caught inside guard of moving machinery	none		
Hit by swinging door	none		
Total	229		

CHART 7

DISTRIBUTION OF ACCIDENTS IN CASCADE MILL OF BROWN COMPANY

YEAR, 1918

Accidents Caused by	No.	Per Cent.
Cut and bruised fingers	67	30.0
Slipping	39	17.0
Hit by loose material when it fell to floor	15	6.0
Moving material, crushed hands	26	11.0
Nails running in feet or scratching hands	17	7.0
Chips flying into eye	15	6.0
Bruised legs, caught between material, etc.	3	1.3
Falling from plank staging	13	5.0
Electric shock	none	0.0
Dropping axe on feet while putting handle in same	none	0.0
Overlifting, wrenched back	3	1.3
Overload, strained muscles	2	0.9
Run into by electric truck	2	0.9
Illness	none	0
Blood poison, sliver in hands	none	0.0
Chlorine spilled	none	0.0
Clothing caught on sprocket	none	0.0
Wagon overturning	none	0.0
Falling off team	none	0.0
Hot ashes	1	0.4
Run over by freight cars, no signal	none	0.0
Hole in floor	2	0.9
Climbing ladder, struck head on moving belt	1	0.4

Hit by falling icicle	1	0.4
Elevator accident	2	0.9
Accidentally dropping material while carrying same. Injuries to feet and legs	11	5.0
Climbing ladder, struck head on bolt	none	
Burns received from tar	none	
Wrenched arm when stretching felt	none	
Putting on belt with stick while machinery was running	none	
Arm caught inside guard of moving machinery	none	
Hand caught in machinery	none	
Hit by swinging door	none	
Total	220	

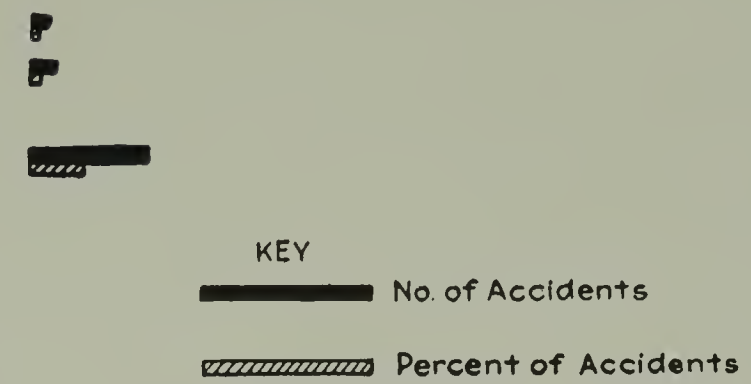


CHART 8

DISTRIBUTION OF ACCIDENTS IN CASCADE MILL OF BROWN COMPANY

Accidents Caused by	Half Year 1919 No.	Calc. to Yearly Basis.	Per Cent.
Cut and bruised fingers	5	10	10.0
Slipping	7	14	14.0
Hit by loose material when it fell to floor	4	8	8.0
Moving material crushed hands	3	6	6.0
Nails running in feet or scratching hands	5	10	10.0
Chips flying into eye	8	16	16.0
Bruised legs, caught between material, etc.	none	0	0.0
Falling from plank staging	none	0	0.0
Electric shock	none	0	0.0
Dropping axe on feet while putting handle in same	1	2	2.0
Overlifting, wrenched back	5	10	10.0
Run into by electric truck	1	2	2.0
Illness	none	0	0.0
Blood poison, sliver in hands	2	4	4.0
Chlorine, spilled	none	0	0.0
Clothing caught on sprocket	none	0	0.0
Wagon overturning	none	0	0.0
Falling off team	none	0	0.0
Hot ashes	none	0	0.0
Run over by freight cars, no signal	none	0	0.0
Hole in floor	none	0	0.0
Climbing ladder, struck head on moving belt	none	0	0.0
Hit by falling icicle	none	0	0.0

KEY

No. of Accidents

Percent of Accidents

Elevator accident	none	0		0.0
Accidentally dropping material while moving same. Injuries to feet and legs	1	2		2.0
Climbing ladder, struck head on bolt	1	2		2.0
Burns received from tar	1	2		2.0
Wrenched arm when stretching felt	1	2		2.0
Putting on belt with stick while machinery was running	1	2		2.0
Arm caught inside guard of moving machinery (killed)	1	2		2.0
Hand caught in machinery	1	2		2.0
Hit by swinging door	1	2		2.0
Total	49			

illustrate the above I submit tables. One mill I shall designate as Mill A and the other as Mill B. I am obliged to do so because the manufacturers, while they do not object to my using the figures, do object to my using their names. I might say that I have been through both mills and know the conditions in each, and consider them fair illustrations of the points for which I shall use them as illustrations.

Charts 6, 7 and 8 show the causes of accidents in the Cascade Mill of the Brown Company for the years 1917, 1918 and half-year 1919.

It will be seen from the above that there has been a marked reduction in accidents. It would be well in making comparisons to bear in mind that the safety work in this mill started in June, 1917. Actual improvements did not get started until August of that year and owing to the shortage of help caused by the war, improvements were slow. It was not until the end of the year 1918 that the majority of improvements were completed. There are still numerous improvements to be made.

Under the heading of "Cut and bruised fingers" you will note that there are more accidents resulting than from any other on record. These accidents happen in various ways, by knives slipping while cutting material, by getting fingers caught in machinery, paper cuts, cuts by saws, etc.

Under the heading of "Slipping" accidents from this cause are caused by wet stairs, greasy and oily floors, passage-ways being blocked by material, etc. Injuries received from this cause range all the way from a sprained ankle to a broken arm.

Under the heading of "Hit by loose material when it fell to the floor." Accidents are caused by loose material overhead accidentally falling to ground floor hitting someone, also by men when lowering material to ground floor not giving warning.

Under the heading of "Moving material. Crushed hands." Accidents are caused by hands getting jammed between material while moving same or falling on hands.

Under the heading of "Nails running in feet or scratching hands." Accidents are caused by men, unintentionally stepping on nails in boards which are left lying around, also by nails projecting out from tables, etc.

Under the heading of "Chips flying into eyes"—accidents are

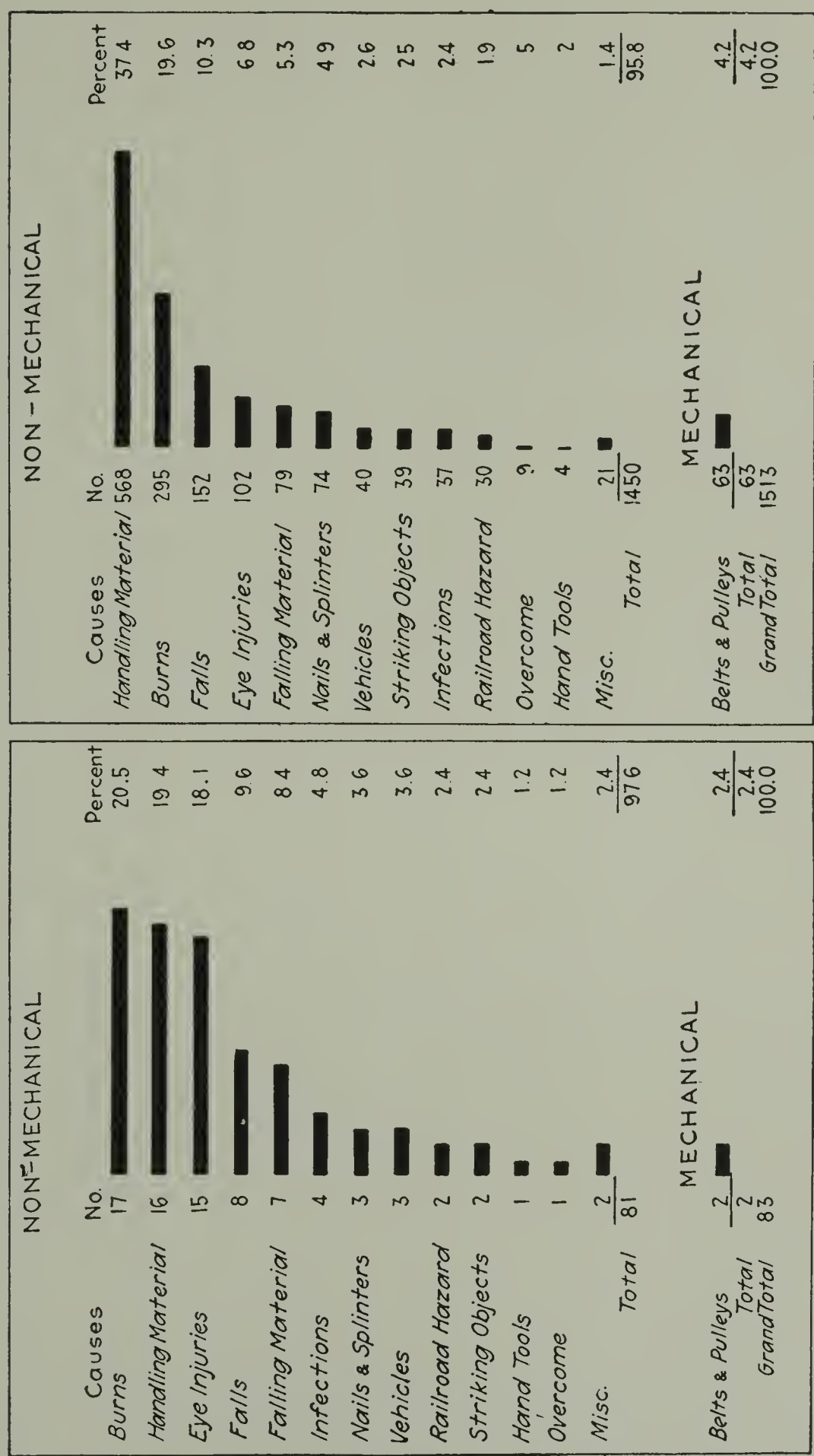


CHART 9.—Merrimac Chemical Co., Everett Plant.—Summary of Lost Time Accidents with Days Lost.

caused by chips of steel, wood, etc., flying into the eyes. Most of the accidents happen around emery wheels.

Under the heading of "Bruised legs, caught between material, etc.," accidents from this cause are the result of men being caught between rolls of paper, machinery, etc.

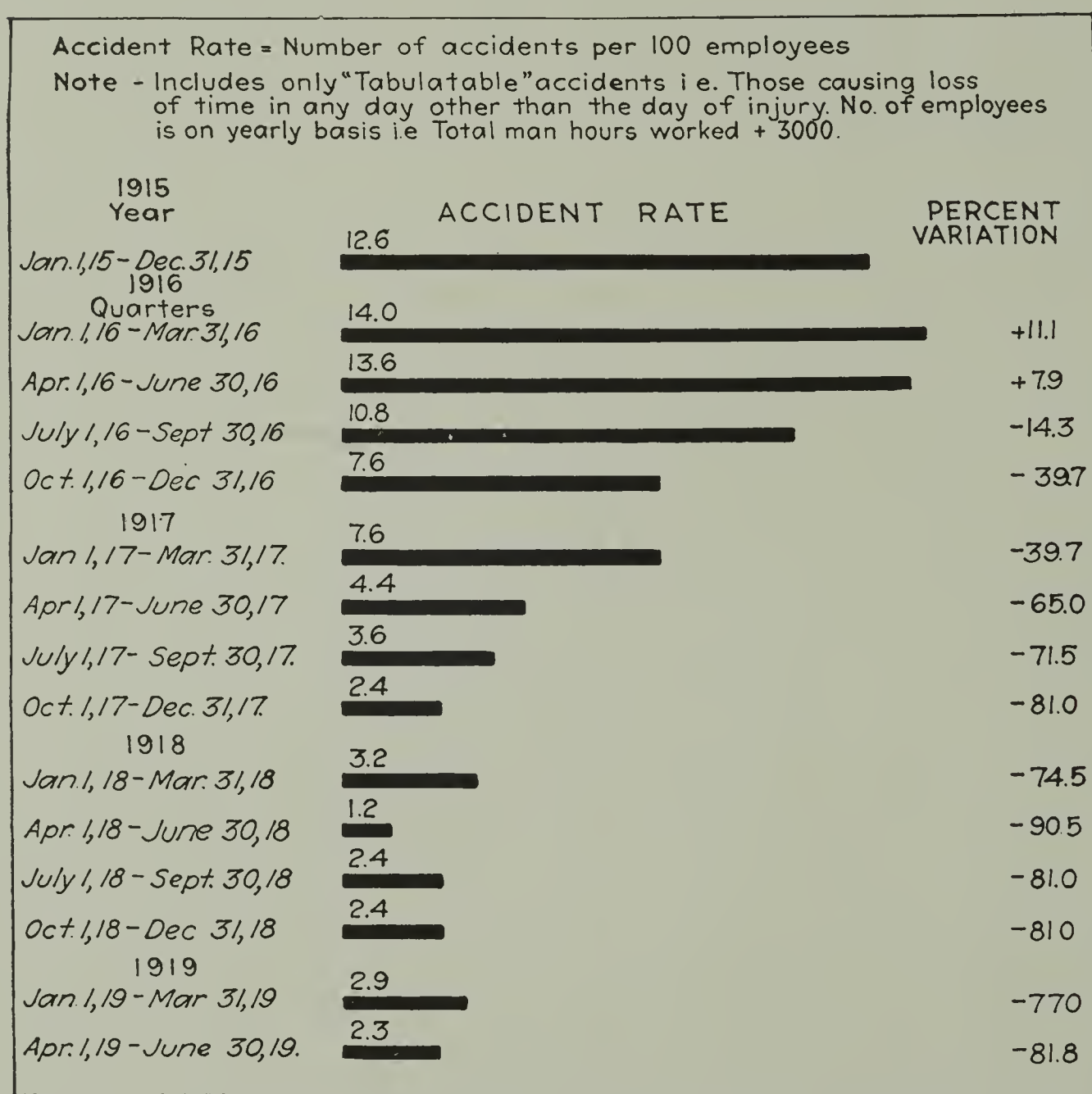


CHART 10.—American Steel and Wire Co., South Works. Variation in Accident Rate.

Under the heading of "Falling from plank staging"—accidents are caused by poorly erected stagings which break down because of too much weight, and also from planks slipping.

Under the heading of "Run into by electric truck"—accidents are caused by alarm not being given in due time of approaching truck. This is the truck that is used in the Sulphite screen room.

Under the heading of "Run over by freight cars, no signal," there has been but one accident from this cause which resulted in man being killed, but there have been numerous narrow escapes. An electric signal system such as is in use at the Burgess Mill, would be a splendid thing to install on the Cross power bridge entrance, also at the Cascade Mill, where cars are shunted down the track without being coupled to the engine.

Other accidents speak for themselves in accompanying report.

Owing to the kindness of Mr. Howard of the Merrimac Chemical Co., I am enabled to present the very instructive material com-

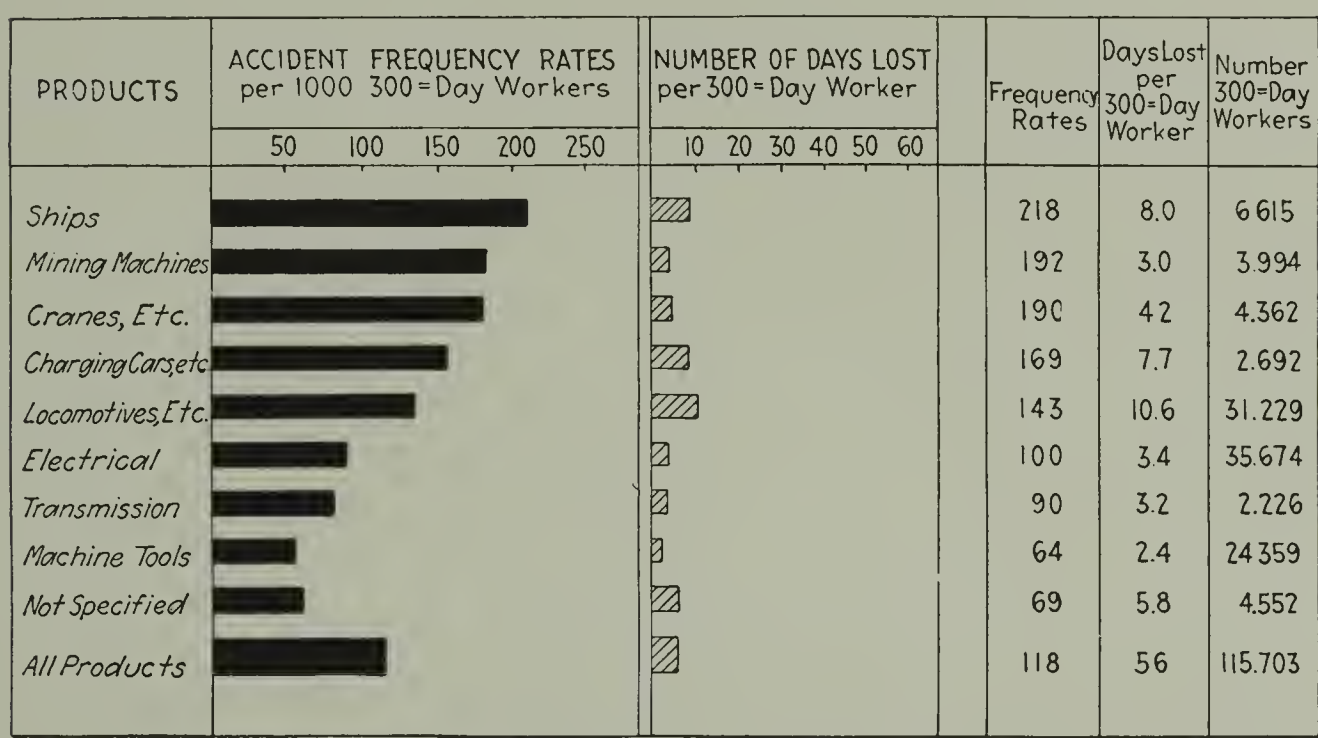


CHART 11.—Frequency and Severity of Accidents in the Machine Building Industry 1912. Combined data for 194 plants classified by products.

bined in Chart 9. You will note that this gives not only the causes of accidents but the days lost for each kind of accident.

Through the courtesy of the Liberty Mutual Insurance Company, I am able to show you in graphical form (Chart 10) the variation in the Accident Rate of the South Works of the American Steel & Wire Company. This is very illuminating as showing what can be done by a systematic effort in accident prevention.

Referring to Table 4 it will be seen that there are a larger number of accidents in certain departments than in others. A table like this is valuable because it will show the location of the greater number of accidents. But if this table is used as a basis of hazard, it will be very misleading. I have obtained from the manufacturers

of Mills A and B the number of employees in each department and have reconstructed a new chart which shows the accidents per thousand in each department.

It will be seen that Table 5 conveys an entirely different impression than does Table 4. If I should present these same facts in table of accidents per thousand in the entire mill the results would appear still different as abnormal results due to small numbers would be eliminated.

I only mention the above to show the necessity of putting your data in correct form.

Even Table 5, though it shows the accidents per thousand,

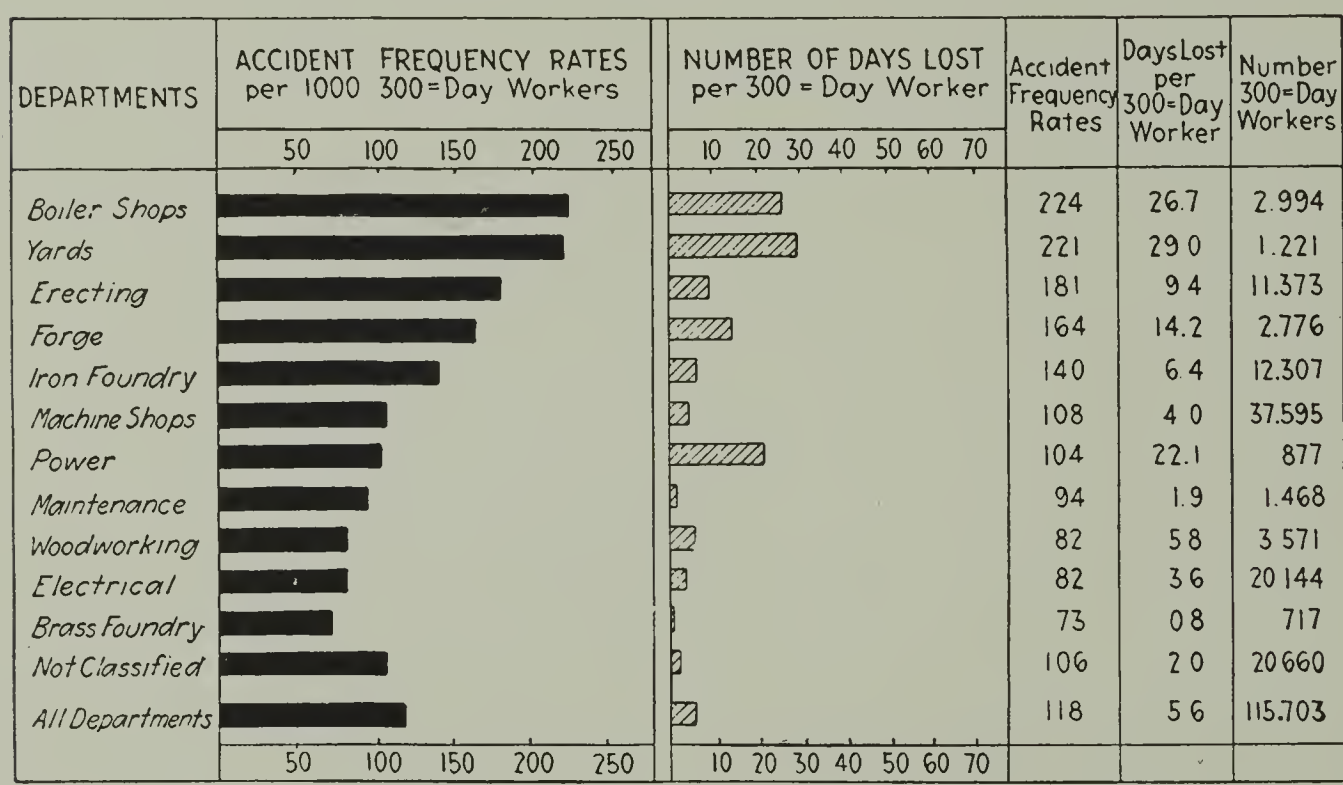


CHART 12.—Frequency and Severity of Accidents in the Machine Building Industry, 1912. Combined data for 194 plants. Showing the variation in accident rates in the important departments and contrasting accident frequency and accident severity (severity being measured in terms of days lost).

cannot be taken as a guide as to which department is the most or least hazardous. As above mentioned, those departments having only a few men therein, which have had the misfortune to have an accident, will show abnormal results. Furthermore, the period for which this data is available is too short. But aside from the above, the data given above is not sufficient to get any idea of the amount of hazard in each department. The above only gives us some idea of the frequency of accidents in the different departments, but gives no idea of the seriousness of such accidents.

To get an idea of the hazard it is necessary to have the severity rate as well as the frequency rate. Chart 11 shows the frequency and severity rates by industries and Chart 12 shows the same for departments. (Both taken from the U. S. Department of Labor.)

In looking over Tables 4 and 5 it will be seen that the accidents per thousand for the same departments vary, viz., wood room and barker mill in Mill A corresponds to the wood room in Mill B. Paper in Mill A corresponds to machine room in Mill B. Maintenance, boiler house and yards are the same on each. The other departments cannot be compared as they are so unlike and also because the number of men in each is so small that the accidents per thousand may be misleading.

Now let us compare these three departments.

TABLE 6

ACCIDENTS PER 1000 MEN

	Wood Room.	Machine Room.	Maintenance.	Yard.	Boiler House.
Mill A.....	9.3	12.2	11.1	15.3	6.8
Mill B.....	28.5	16.4	22.9	19.6	11.3

There is evidently some reason for this discrepancy in the two mills for life work. It is not lack of accident prevention methods as both mills are doing all they can along these lines. The trouble is evidently elsewhere. As these mills have kept no severity records we cannot tell if the reporting of accidents in each is on the same basis. This must be remembered when considering the following facts which may be indicative but which are not proved.

TABLE 7

ACCIDENTS PER 1000 MEN

		% French	% Russians	% English speaking
Wood room:	Mill A....	34.2	11.4	54.4
	Mill B....	53.7	38.0	8.3

TABLE 8

		% French	% Russians	% English speaking
Machine room:	Mill A....	35.1	0.0	64.9
	Mill B....	74.5	7.2	18.3

TABLE 9

		% French	% Russians	% English speaking
Maintenance:	Mill A....	46.2	0.0	53.8
	Mill B....	65.0	10.4	24.6

TABLE 10

		% French	% Russians	% English speaking
Yard:	Mill A....	52.5	6.1	41.4
	Mill B....	20.0	41.4	38.6

TABLE 11

		% French	% Russians	% English speaking
Boiler House:	Mill A....	38.2	0	61.8
	Mill B....	33.3	0	66.7

It will be noticed from the above that there seems to be some relation between the frequency of accidents and the non-English-speaking people employed. In all but the last case in the above-given data we find that when the percentage of non-English speaking is the larger, so also is the percentage of accidents the larger. In the last case the boiler house in Mill B is a new house, which tends to reduce accidents. In addition to this we find that in neither Mill A or Mill B are there any Russians in the boiler house.

In order not to be misunderstood, I want it to be understood that I have ascertained that many of the French speak English. I have also ascertained the additional fact that very few of the Russians speak English.

Now it must be remembered that the above is only indicative of a line of investigation which may be both interesting and profitable. The data given is too meager for us to base any fixed conclusions. Assuming that future investigations prove the above to be true, the question then arises, how much is due to misunderstanding of instructions and how much is due to stupidity. The French are much more mentally alert than the Russians so that no exact basis can be arrived at by basing conclusions on the sum of the non-English-speaking races. Investigations should cover not only the nationalities mentioned above but all nationalities. If a list of accidents by nationalities were kept it might throw some light on this subject but it would not be conclusive, as many accidents may be due to the fault of others.

I submit Chart 13 taken from the U. S. Bureau of Labor. The results shown therein tend to more or less confirm the above partial observations.

If statistics could also be found showing the frequency and severity rates before accident prevention was installed and after it got working properly, we might then be able to compare the relative improvements of the different nationalities. This I think would throw a tremendous amount of light on this subject.

Another factor which should be studied in relation to accident prevention in the mill is frequency and severity rates of night workers vs. day workers. I have reason to believe that both the

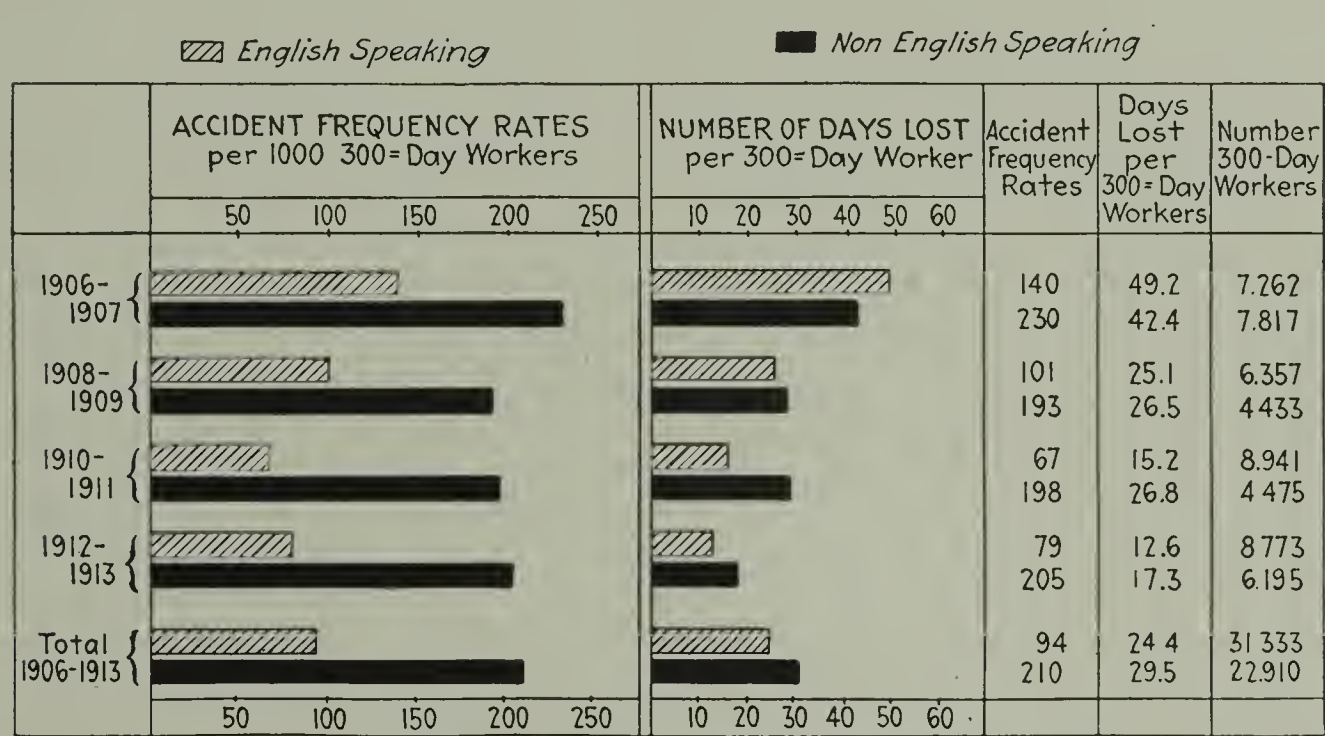


CHART 13.

frequency and the severity rates are greater at night than in the daytime. I hesitate to give any figures on the above as my data is even more incomplete than in regard to the effect of nationalities. Chart 14, however, shows some light on this subject.

I might mention many more conditions which seriously effect accident rates, but to do so would drag this paper out to an interminable length, so I must refrain. I cannot, however, leave without interjecting the remark that no basic facts can be arrived at until both frequency and severity rates are kept.

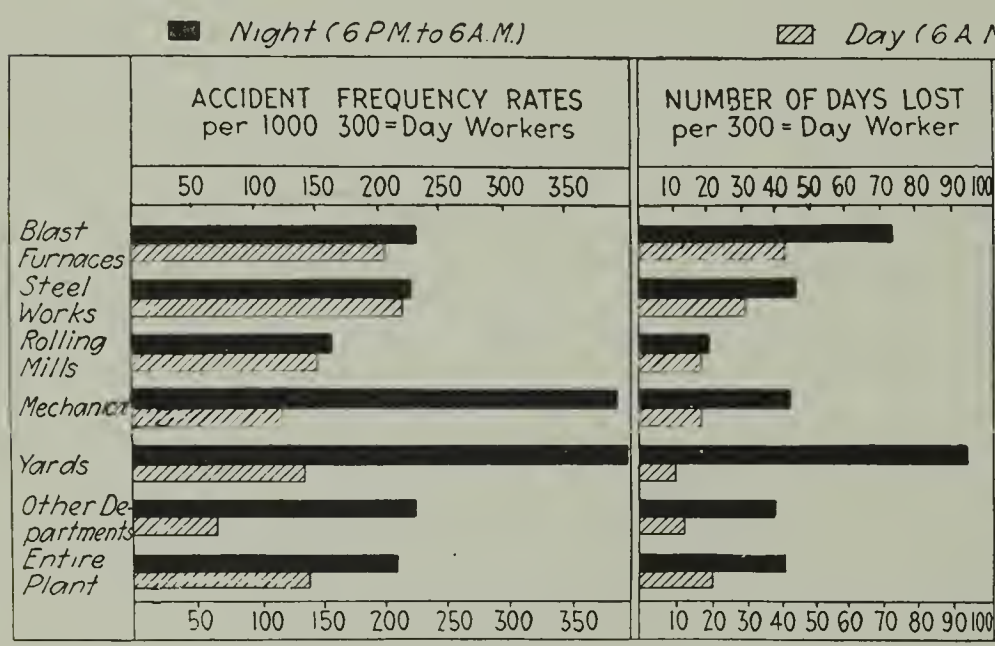
I cannot go into this subject here but refer you to the various bulletins of the United States Department of Labor.

As an indication of what can be accomplished in a short time

I give herewith a record of what has been done in the Cascade Mill of the Brown Company.

I wish I had time to go into details as to methods under consideration and the methods which have been adopted, but as to do so would take a volume in itself, I will refrain, giving only a brief summary of the results, with a few accompanying suggestions, obtained in the Cascade Mill of the Brown Company.

1. Owing to machines in some parts of the mill being so close to each other, it was necessary for oilers in order to reach oil cups to crawl under unguarded belts, pulleys, and shafts, there was nothing to prevent them from meeting with serious injury in case of slipping. This danger has been eliminated by building



	Accident Frequency Rates	Days Lost per 300=Day Worker	Number 300=Day Workers
Blast Furnaces	229	74.6	2.879
	204	42.6	6.413
Steel Works	224	46.2	3.638
	218	30.5	5.045
Rolling Mills	160	21.1	6.516
	150	18.1	10.789
Mechanical	389	44.3	556
	122	19.1	7.767
Yards	399	95.4	.874
	139	11.7	5.083
Other Departments	227	40.4	1.209
	69	14.8	9.880
Entire Plant	214	43.2	13.672
	142	22.2	44 977

CHART 14.

guards under and over belts, also around sections of shafts, also around pulleys where these men have to crawl under. Oil pipes have also been built to upper platform wherever possible, so that oilers can perform their work without any risk. While there were not many accidents from this cause, yet the few there were proved to be serious. Since improvements have been made over a year ago, there have not been any accidents from this cause.

2. Loose planks strung over open places in mill for men to stand on while working on belts, valves, pumps, etc., were replaced by platforms with railing, also stairs and railings to platforms. Before improvements there were several accidents each month from this cause, since improvement there have been no accidents reported.

3. Ladders which were used to reach apparatus installed overhead were replaced by stairs and railings, ladders being used in places only where there is not sufficient room to install permanent stairs and rails. Numerous accidents have been eliminated by the use of stairs with railings, the cause of which in the majority of cases was due to steps becoming very slippery, due to oil and grease, resulting in men slipping and injurying themselves; stairs and railings have proven much more safe for men especially when they are carrying material. There has not been an accident reported from this cause since improvements mentioned were made over a year ago.

4. Proper lighting system should be installed in any place where workman or other has to travel; our Safety-Committee, which is composed of employees from the various departments of this mill, consider this matter a big help in the matter of reducing the number of accidents in any line of work.

5. Boards left lying around with nails in them, also nails projecting up from floors, tables, etc., prove to be the biggest problem that our Safety Committee has to handle. The number of accidents from this cause has been reduced at least 50 per cent by having all boards carefully piled up in an "out of the way" place, also by the wide awakeness of men when seeing nails projecting upwards to use their hammers in correcting same. The most of our accidents at the present time are caused from cuts by nails, as mentioned, some of which are slight, while others prove serious because of blood poisoning setting in with the result of considerable time being lost by the men so afflicted.

6. Injuries to the eyes while in most cases are slight, prove to be the next biggest problem. These injuries are received by pieces of wood, steel, iron getting into the eyes. Safety goggles prove to be the best remedy to prevent accidents from this cause. The Company has distributed safety goggles in the various departments of this mill to be used by men performing work where there is a chance of chips, etc., getting into the eyes. On planning machines safety devices were installed deflecting the course of chips, etc.

7. Warnings issued by men when they are lowering material from overhead to the ground floor have reduced the number of accidents from this cause considerably. While there are still accidents from this cause, they are mostly caused by the younger element now in the mill and who have not as yet been broken

in to the safety methods. These new men in a short time are taught safety methods by the older men and more especially by the bulletins of the National Safety Council.

8. Clear passage ways in all places have done away with climbing over material, etc., which heretofore have caused a number of accidents, by men slipping and injuring themselves.

9. Men working around moving parts of machinery should at all times have tight fitting working clothes; loose, ragged sleeves, coats and overalls, often catch on moving parts of machinery. Sleeves should be rolled up above the elbows. There have been a few accidents from this cause, which have since made other men more careful.

10. Slippery floors constitute an element of danger, especially in conjunction with unguarded machinery. And even where a slippery floor is not in proximity to an unguarded machine, it may yet cause a bad fall, resulting in serious injury. This is likely to be the case where workmen are engaged in carrying heavy material.

11. Carelessness. More accidents have occurred from this cause than any other cause on record. The National Safety Council Bulletins are a big help in eliminating carelessness when posted up in places where all men can read and see same. Lack of discipline is an encouragement to carelessness, and should be corrected. Under the conditions the employer is warranted in making strict rules governing the employees of the plant. In fact, it is his duty to do so. By the maintenance of discipline, to which punitive measures are added where necessary, many accidents may be prevented. Disobedience of orders should not be tolerated.

12. Failure to use safeguards provided. It is not very common to find this to be the case, but when such occurs it sooner or later results in a serious accident. We have had several accidents from this cause, some of which proved fatal, the others very serious. Some workmen fail to use safeguards provided for the reason that "it is too much trouble," "takes too much time," and as one man said, "I have been doing it this way for twenty years and have never had anything happen to me," but the poor fellow with a big family, got hurt seriously from this very same cause some months ago, and will have part of his body crippled for life. The only remedy for this cause is by the exercise of considerable ingenuity. The guard may often be adopted to perform its function and yet not interfere with the speed of the work. No guard

should be condemned simply because the workman at the outset objects to its use. Rather this should lead to further study of

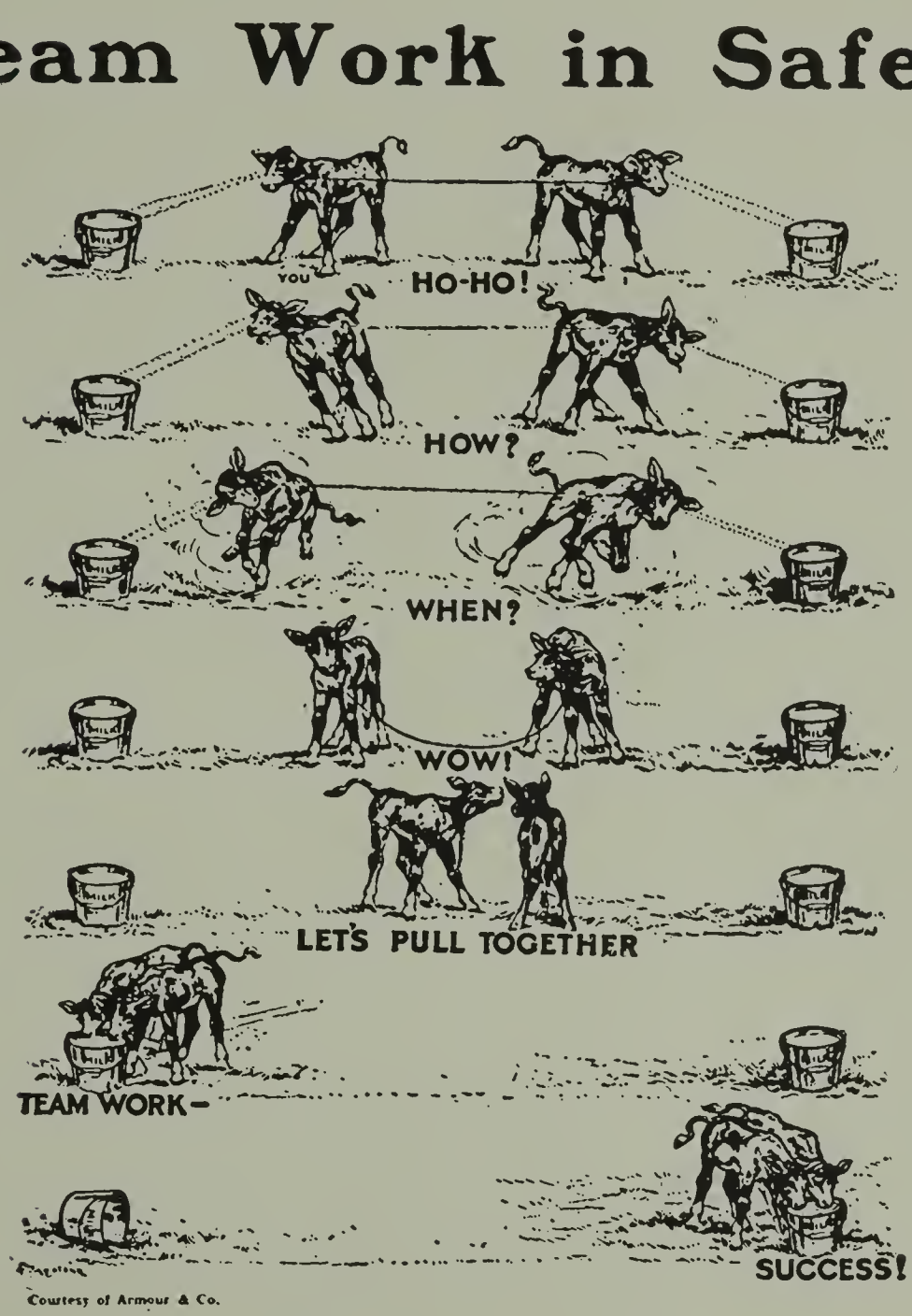


CHART 15.

the matter and modification of the guard to suit the conditions. Failing in that, then discipline is next.

13. Rules. The education of the workmen in proper and safe

practices will be promoted by the posting of printed rules regarding the things they should avoid doing, and the precautions they should take to avoid accidents. In the case of especially dangerous machines, it is advisable to furnish the operatives with special rules and instructions relative to their operation. It is also particularly important to warn workmen of dangers not apparent except to experienced and intelligent men, and to show them how such dangers may be avoided.

14. Inspections. Regular and frequent inspections by competent men are made of all the ways, works, machinery and appliances, so that defects and unsafe conditions may be discovered promptly and remedied.

We are now in the process of greatly enlarging our Research Department and the resulting confusion interferes greatly with our work. After building operations thereon cease, we hope to establish in the research department a branch of research devoted entirely to the prevention of accidents.

As a pictorial illustration I submit Chart 15. This conveys the idea with a punch.

In closing I cannot resist the temptation of making a few suggestions:

Owing to the importance of this subject I suggest that at our next meeting we have a symposium on accident prevention in the mill.

The subject should be divided into sharply defined topics and each topic assigned to a competent speaker with the understanding that he confine himself to matters solely within his assigned topic. By so doing we can cover much more ground, as we will then receive more information on the subject in its various phases and at the same time have less repetition of facts brought out by other speakers. These should be assigned far enough in advance to allow proper time for preparation.

As a tentative proposition I suggest that the subject be divided in the following way:

a Initiative.
b Organization.
c Education.
d Hygienic conditions.
e Occupational conditions.

f Physiological conditions.
g Psychological conditions.
h Occupational disease.
i Social diseases.
j Social welfare.
k Fatigue.
l Overturn in the Mill.
m Mechanical and Engineering devices.
n Research work.
o Statistical.

Also in connection with the above I suggest that papers on topics of such special interest as those listed below be given:

1. Psychological tests on men entering the mill.
2. The moron and his relation to accidents.
3. Assigning of a job to the moron which is well within his capabilities.

APPENDIX.

I had not intended to go into the question of Frequency Rates and Severity Rates, but on reading this paper to a few friends of mine I find that there is a misunderstanding of these terms.

In some occupations there may be numerous accidents, but the nature of the work and equipment may be such that the injuries are all relatively slight. The cook, for instance, may receive many small cuts and burns, but the injuries are not serious.

On the other hand, we may have an industry where the accidents occur less often, but that the work is such that when an accident does occur it is of a very serious nature. A foundry man will illustrate this class of occupations. If you simply tabulated by number of accidents, the accidents happening to the cook will be large while the accidents happening to the foundry man may be small. The bare values thus tabulated or plotted would make it appear that the cook's job was the more hazardous. Anybody who has even a superficial knowledge knows that this is an absurdity. We thus see by keeping frequency of accidents only we are liable to deceive ourselves.

In order then to get a basis for the comparison of hazard it will be necessary to have some standard method of measurement for both frequency and severity. If the labor was constant the

problem would be much simpler than it is. The hours of labor in different mills vary and the amount of labor in the same mill fluctuates up and down. It can readily be seen that if a man works ten hours a day while another works only eight hours, the chances of the first man getting hurt are five as against the second man's four.

Thus, to establish a standard we first have to standardize the day. As a basis 300 ten-hour days are recommended, viz., 3000 hours per man. Suppose, for instance, we have a plant which has a labor charge of 5,400,000 hours in a year, then irrespective of whether it ran on an eight-hour basis or a ten-hour basis, the number of full-time workers used for accident statistical workers would be 1800. By using the full-time worker of 3000 hours per year for every plant, comparisons can be made irrespective of whether the plant runs by fits and starts eight or ten hours a day.

Now if this plant had 360 accidents, the frequency would be 200 full-time workers per 1000.

It may seem that the unit thus established is a statistical abstraction, and to a certain extent it is, but when you consider that the average workman works 3000 days a year if in good health and that the 3000-day workman is only a unit of measure, I think you will see that it is not out of reason and may form a valuable basis of comparison.

Suppose another plant had 18,000 hours of labor charged up in a year, then the number of full-time workmen would be 6 and if this plant had 3 accidents charged up we should have a frequency of 500 per 1000 full-time workers, so that the relative accident frequency of the two plants would be as 200 is to 500.

Now let us see what measure we can obtain for severity. Evidently compensation cannot be used as a basis for it varies in different States. For the same reason loss of wages cannot be used for the wages paid even in the same State vary even more than does the compensation. We still have another unit and that is days of labor lost. This will measure more or less the quantity, so to speak, of the accident. This gives us a measure to a certain extent of the severity of those accidents in which the worker finally returns to work. But what shall we do with an accident which finally results in death? Of course we have no means of knowing how long that individual person would have lived and so we cannot say how much time this accident cut off from his

existence. But we can again resort to a statistical abstraction, which though it may not be correct for any individual case may be correct for the average of a number of cases.

Insurance companies figure that a man's working period is sixty years and they also find that averaging the ages from all the deaths, that they arrive at a figure which is approximately thirty. The difference represents his time lost, viz., 30 years, which at 300 days is an economic loss of 9000 days. In the case of permanent disablement we have a yet harder task. In this case not only is the worker's productive capacity *nil* but the worker is a constant source of expense.

Without going into the methods by which a figure is given to the above I will state that that figure is set at 35 years' lost time as 10,500 days. The time consideration for accidents in which partial disablement results has already been given in the first part of this paper. From the information given above we can now figure out the severity rate.

The following example is taken bodily out of U. S. Department of Labor, 26-13:

"Plant X operated 4,200,000 man-hours in 1915, requiring 1400 full-time (300-day, 10-hour-per-day) workers. During the year 324 accidents occurred, resulting in one death and the loss of the following members: 2 arms, 1 foot, 5 thumbs, 25 first fingers, while the 290 temporary disabilities showed a time loss of 2790 days. Applying the time losses in the above table to these data, the following results are obtained:

TABLE 12

TIME LOSSES IN ONE PLANT

Items.	Time Loss (in Days).	
	Per Case.	Total.
1 death	9,000	9,000
2 arms	2,808	5,616
1 foot	1,845	1,845
5 thumbs	540	2,700
25 first fingers	414	10,350
290 temporary disabilities	.....	2,790
Total	.....	32,301

The total number of days lost, 32,301, divided by the number of full-time workers, 1400, gives an average of 23 days per full-time worker. This is what is here called the accident severity rate, expressed in terms of days. The accident frequency rate for the same group per 1000 full-time 300-day workers would be 324 divided by $\frac{1400}{1000} = 231$.

Illustrations of the Use of Severity Rates.

The preceding paragraphs explain the meaning of accident severity rates and the method by which they are obtained. The significance of such rates in their practical application is indicated in the two following illustrations.

In the table below comparison is made of the accident experience for a year of the iron and steel industry as represented by a large plant, and of a machine building industry as represented by a group of plants. Frequency rates and severity rates are shown in parallel columns:

TABLE 3

Accident Rates in Steel Manufacture and in Machine Buildinb

		Accident Frequency Rates (Per 1000 300-Day Workers)				Accident Severity Rates (Days Lost Per 300-Day Worker)			
Industries.	No. of 300-day Workers.	Death.	Permanent Disability.	Temporary Disability.	Total.	Death.	Permanent Disability.	Temporary Disability.	Total.
Iron and steel (1913).....	7562	1.9	4.6	108.0	114.5	16.7	2.2	2.4	21.3
Machine building (1912).....	115703	.3	3.6	114.1	118.0	2.9	1.6	1.1	5.6

Examination of the columns giving total frequency rates and total severity rates show that, on the basis of frequency, the machine-building plants were more hazardous than the steel plant—the respective rates being 118 as against 114.5 per 1000 full-time workers. On the basis of severity, however, the steel industry was almost four times as hazardous as machine building—the days

lost per full-time worker being 21.2 and 5.6 respectively. It is clear that as between these diametrically opposite showings of the relative hazards of the two industries, the severity rates offer a decidedly more accurate measure of true hazard. In machine building there is opportunity for many minor injuries, but the danger of serious injury is much less than in the steel industry. The severity rate brings out this fact. (See Charts 11, 12, 13 and 15.)

THE RESISTANCE OF ABSORPTION TOWER PACKING TO GAS FLOW

By FRED C. ZEISBERG

Read at the Savanah Meeting, December 5, 1919

THE past few years have seen an enormous increase in the manufacture of various types of tower packing, and several patents have been taken out on designs developed by various inventors and manufacturers of chemical pottery. Acid manufacturers have been quick to recognize the advantages possessed by these manufactured packings, and have largely replaced the pumice, quartz or coke formerly used, with rings, blocks, etc. While an improvement in absorption has nearly always accompanied the adoption of one of these modern packing materials, no numerical method of expressing this advantage has been available except the figures on surface and free space. quoted by the manufacturer of the packing, and these are frequently erroneous.

For this reason E. I duPont deNemours & Co. undertook a study of various types of tower packing, with the purpose of checking up definitely the surface and free space figures of not only the artificial packings, but also of quartz, coke, etc., and more important still, to investigate the resistance to gas flow offered by the various types of packing in common use. In large absorption systems the resistance to gas flow is an important consideration, since if improperly designed, the system will require excessive pressures to bring about the necessary gas flow. It was hoped that the data obtained would stimulate packing manufacturers to produce newer and still better types of packing.

The projected study was mentioned to Mr. Hood, of the B. Mifflin Hood Brick Co., and he very kindly offered to donate such of his products as we might wish to test. His offer was accepted and the following packing material was furnished by him: $3'' \times 3''$ corrugated diaphragm rings, $3'' \times 3''$ corrugated spiral rings, $6'' \times 6''$ corrugated spiral rings, $6''$ Hechenbleikner blocks, and $1\frac{1}{2}'' \times 4'' \times 8''$

chemical ware tile. The General Ceramics Co. also loaned us a supply of 1″ Raschig rings.

The figures for the surface of the packing materials were calculated from measurements, and are expressed as "square feet per cubic foot." Since many of the British journals express this figure as "square yards per cubic yard" and the French and German journals as "square meters per cubic meter," it may be desirable to point out here that all of these values are of a different magnitude. One square foot per cubic foot is equivalent to 3 square yards per cubic yard or 3.28 square meters per cubic meter. With quartz and coke, of course, the measurements are approximate only, and consequently surface figures for these materials do not possess the accuracy of those for the manufactured packings. It might be well, also, to point out that in the case of the manufactured corrugated packings the assumption was made that the corrugations did not add anything to the surface, which is not strictly true.

The free space of a packing is the interstitial space. It is the space through which the gas must pass and is expressed as a percentage. Thus, a free space of 50 per cent means that in 100 cubic feet of packing material 50 cubic feet of gas passages exist. The free space herein reported was obtained by calculation, by taking into consideration the number of pieces of packing required to fill a known volume, together with the average weight per piece and the apparent specific gravity of the packing material, or by actually weighing the amount of packing material, whose apparent specific gravity was known, required to fill a known volume. The free space naturally varies with the type of packing and with the manner of disposing it in the tower.

The resistance offered by a tower packing to gas flow is, of course, dependent upon both the free space and the surface exposed, but just what effect each might have it is impossible to predict. For this reason air was actually blown through a variety of packings under various conditions and the resistance was actually measured.

The experimental equipment consisted of a Wilbraham-Green positive-pressure blower connected with a series of chemical ware absorption towers 30″ in diameter and approximately 15′ high. The air passed into the bottom of each tower in succession, being carried from the top of one tower to the bottom of the tower following by an 8″ pipe. A valved side connection in the pipe to the first tower was provided, so that the amount of air passing

into the tower could be regulated by spilling the excess to the atmosphere. The air passing into the tower was measured with a Pitot tube of glass, of the American Blower Co. type, and differential manometers, protected from velocity pressure effects, were provided at the bottom and top of each tower, to measure the static pressure at those points. A carefully measured height of the packing to be tested was supported on a checkered brick pier in the bottom of the tower. The resistance offered by this pier to an air flow much larger than is ever likely to be met in practice was actually determined to be negligible. In some cases a series of measurements was made simultaneously in several towers, but since the results thus determined were found to be in good agreement the later tests were run on only one tower.

Since the constants to be shown later in tabular form, together with other characteristics of various types of packing, will be unintelligible without explanation, it is desirable at this point to give some attention to the theoretical considerations involved.

Assuming that the general law of the flow of fluids holds in this case (this was experimentally demonstrated to be true), the frictional resistance is proportional to the square of the velocity of flow. This resistance may be expressed as the pressure necessary to produce the given flow.

Let s = linear velocity in feet per minute;
p = pressure in inches of water;
k = a frictional constant;
a = area of cross-section of packing in square feet;
h = height of packing in feet;
v = volume of air passing in cubic feet per minute.

Then $$p = ks^2, \quad \ldots \quad (1)$$

and $$s = \frac{v}{a}. \quad \ldots \quad (2)$$

Therefore $$p = \frac{kv^2}{a^2}. \quad \ldots \quad (3)$$

Since the resistance, or the pressure, varies directly as the height of the packing, we may hence write

$$p = \frac{khv^2}{a^2}. \quad \ldots \quad (4)$$

However, k is a general constant, varying in value with the type of packing. We have therefore designated f as the frictional coefficient of one square foot of packing one foot high, and may write equation (4) as

$$p=\frac{fhv^2}{a^2}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

f of course differs for each style of packing, with its method of disposal in the tower and with the amount of liquid circulating in the tower. In order to make f more descriptive, superscripts and subscripts have been added, as follows:

f^d = packing dumped into tower;
f^s = packing stacked, *i.e.*, arranged regularly in layers, but with no attempt to have pieces in one layer in any way related to those in adjacent layers;
f^p = packing packed, *i.e.*, arranged regularly in layers, with the axes of pieces in adjacent layers coinciding;
f_d = packing dry;
f_w = packing wet with water but drained as completely as possible;
f_c = packing with water circulating over it at a rate of 11 lbs. per square foot cross-sectional area per minute.

It is, of course, evident that we may have, for example, $f_d{}^d$ = packing dumped and dry, and that quartz, coke, etc., can give values only for f^d, and not for f^p or f^s.

The frictional coefficient was then determined for various packings under various conditions, by measuring the pressure drop through a tower filled to a known height with the packing, and calculating this value to the standard condition of one foot cube. These values of f, together with other characteristic data, follow in table form. It should be emphasized that the frictional coefficient values are not accurate to more than two significant figures, and in some cases the second figure is in some doubt.

These figures speak for themselves; nevertheless, a few of the more obvious facts will be pointed out. For instance, it is interesting to note how rapidly the resistance to gas flow increases with decrease in size of material (see quartz). That this resistance is not entirely a function of the surface exposed by the packing is indicated by the fact that as the size decreases the resistance increases first less rapidly than the surface and then considerably more rapidly. Another interesting fact is the increase in resist-

TABLE I

CHARACTERISTICS OF VARIOUS TOWER PACKINGS

Packing	Multiply Constants by 10^{-7}									% Free Space	Surface sq. ft. per cu. ft.	Wt. lbs. per cu. ft.	No. Units per cu. ft.
	f_d^d	f_w^d	f_c^d	f_d^s	f_w^s	f_c^s	f_d^p	f_w^p	f_c^p				
Quartz, 6″	58	60	60	..	..	..	..	..	..	44	6.3	89	..
Quartz, 3″	101	110	139	..	..	..	..	..	..	46	12.7	86	..
Quartz, 2″	384	396	433	..	..	..	..	..	..	46	18.7	88	..
Quartz, ½″ to 1″	672	865	1095	..	..	..	..	..	..	47	50.3	88	..
Coke, 3″	76	81	94	..	..	..	..	..	..	58	12.7	29	..
Coke, ½″ to 1⅛″	289	380*	..	..	..	..	..	..	..	..	..	..	..
4″×3″ smooth diaphragm rings	51	56	63	25	34	38	..	32	34	64(1)	20.0	50	27
										51(2)	27.0	66	36
										51(3)	27.0	66	36
3″×3″ corrugated diaphragm rings	51	56	63	31	42	58	26	28	28	65(1)	24.0	48	53
										57(2)	30.0	61	67
										55(3)	31.0	63	70
3″×3″ corrugated spiral rings	45	54	63	54	54	61	..	..	..	72(1)	22.0	40	48
										64(2)	29.0	53	63
6″×6″ corrugated spiral rings	..	..	..	38	47	50	24	31	35	58(2)	15.0	53	8
										58(3)	15.0	53	8
6″ corrugated Hechenbleikner blocks	16	36	36	35	38	38	26	28	28	72(1)	10.7	39	4.2
										62(2)	14.3	52	5.6
										62(3)	14.3	52	5.6
1″ Raschig rings	345	345	345	..	..	..	..	..	..	73	58.0	40	1350
Tile on edge, unstaggered	..	..	..	..	..	..	31	31	43	59	10.5	62	16
Tile on edge, staggered	..	..	..	..	..	..	18	24	31	75	6.4	35	9.5
Tile on edge, staggered	..	..	..	..	..	..	31	33	35	55	11.6	68	17.5
Tile on edge, staggered	..	..	..	..	..	..	43	43	74	45	14.0	81	21
Tile staggered. Alternate rows flat	..	..	..	..	..	..	41	48	57	49	13.2	77	20

* Wet with 92% sulphuric acid instead of water. (1) dumped. (2) stacked. (3) packed.

ance, with the smaller packings, due to a mere wetting of the packing. Often the difference in resistance between a dry and a wet packing is greater than the difference between a merely wet packing and the same packing with considerable water circulating over it.

Perhaps the most noticeable thing brought out by Table I is the fact that for a given size of packing the manufactured packings give much more surface and greater free space, and interpose much less resistance in the absorption system, than quartz, coke or packings of that kind. Many other points will be obvious to the reader.

An example of the application of the resistance constants may not be amiss. Suppose it is desired to find out what pressure will be necessary to force 250 cubic feet of air per minute through an absorption system composed of five towers 2 feet in diameter and filled 10 feet deep with absorption material, when 3-inch quartz is used and when 3-inch spiral rings, stacked, are used, the rate of water circulation being 5 pounds per square foot cross-sectional area per minute.

The cross-sectional area of the packing is $2^2 \times \frac{\pi^2}{4} = 3.14$ square feet. The total height is $5 \times 10 = 50$ feet. For quartz f_c^d would be about $120 \times 10^{-7} = 0.000012$ and for spiral rings about $58 \times 10^{-7} = 0.0000058$ (since the rate of circulation for f_c in Table I was 11 pounds per square foot per minute, values are assumed about half-way between f_w and f_c).

We have seen from equation (5) that the pressure is $p = \frac{fhv^2}{a^2}$, or, substituting, $p = \frac{0.000012 \times 50 \times (250)^2}{(3.14)^2} = \frac{0.000012 \times 50 \times 62500}{9.88} = \frac{37.5}{9.88} = 3.8''$ H_2O for quartz. *Ans.*

For spiral rings the pressure would be $3.8 \times \frac{0.0000058}{0.000012} = 1.8''$. *Ans.*

In closing this paper the writer wishes, first, to thank E. I. duPont de Nemours & Co. for permission to publish these results, and, second, to acknowledge the great assistance of Dr. Guy B. Taylor in obtaining the figures, the actual carrying on of the experimental work being in his hands.

DISCUSSION

Mr. Fairlie: May I ask if in the judgment of Mr. Zeisberg there is any reason to be assigned for the increase in the packing other than merely the weight on the surface?

Mr. Zeisberg: I think that it is undoubtedly a question of capillarity. When the surface of the packing is dry there is room for circulation of air even in the exceedingly narrow spaces adjacent to the points of contact of the packing, but if it is wet these narrow spaces fill up due to capillarity and the free space of the packing is reduced. The smaller the packing the more of these narrow spaces there are to fill up with liquid, consequently the effect of wetting is more pronounced with the smaller packing.

In the region where these experiments were made the humidity of the air was so high during experimentation that there was little opportunity for variation due to evaporation from the wet packing.

Mr. Howard: Mr. Chairman, I think this paper is very interesting, and I am wondering whether Mr. Zeisberg carried out any experiments looking toward the efficiency of absorption; whether in those different kinds of packing the efficiency would be directly in proportion to the surface.

Mr. Zeisberg: I might say that the purpose of carrying on these experiments was to investigate that very point. We have not, however, concluded the experiment. Our interest in the problem was from the standpoint of nitric acid absorption, in which the free space plays a very important part. We hope to continue these experiments and investigate that point, and hope to publish the results at a later time, to show what relation there is between surface, free space, and absorption efficiency.

THE RECOVERY OF PYRIDINE FROM BY-PRODUCT COKE OVENS

By F. E. DODGE and F. H. RHODE

Read at the Savannah Meeting, Dec. 3, 1919

Among the comparatively less important components of coal tar are the so-called "tar bases" pyridine, quinoline, isoquinoline, and their homologues. These tar bases are formed during the coking process, either as primary products from the thermal decomposition of the coal substance or as products of secondary reactions occurring in the gases. When the coal tar is distilled, most of the pyridine and its lighter homologues come over with the light oil fraction; while quinoline, isoquinoline, and the higher homologues of pyridine are concentrated in the carbolic oil. By extracting these oils with moderately dilute sulphuric acid, separating the resulting pyridine sulphate solution from the oil, and liberating the tar bases with an alkali, the crude tar bases may be obtained. From the crude bases pure pyridine or "commercial pyridine" of various grades may be prepared by further purification and rectification. (It may be noted here that the term "pyridine," as used commercially, is applied, not only to true pyridine (C_5H_5N) but to all of the various tar bases, in somewhat the same way that the term "benzols" is used to include all of the simpler homologues of benzol.

Until fairly recently the supply of pyridine from the coal tar oils, although comparatively small, was sufficient to supply the demand. However, the growth of the American chemical industries which has taken place within the last few years has developed new uses for the pyridine bases, and has greatly increased the amounts required for the purposes for which it was formerly used. The development of the dyestuff industry has created a demand for anthracene and carbazole, and in the purification of each of these products pyridine is used. The use of light pyridine as a denaturant for alcohol is being introduced to some extent

into this country and some grades of tar bases are finding application as solvents for certain industrial processes. Moreover, the process for the recovery of pyridine bases from tar oils is a rather costly one and the pyridine thus obtained is so expensive as to prohibit its use for some purposes for which it would otherwise be suitable. Finally, the tar bases obtained from the oils consist largely of the "heavy pyridine" (quinoline, isoquinoline, etc.) for which only a comparatively slight demand exists, and contain relatively little of the more valuable light pyridines. In view of these facts it became evident that a larger and less expensive source of light pyridine bases must be developed if the increasing demand was to be met.

In the development of new sources of pyridine the first problem which presented itself was the determination of the amount of pyridine in the coke oven gases which escaped condensation with the tar. In view of the fact that the lighter pyridine bases have distillation ranges somewhat corresponding to those of benzol, toluol, and solvent naphtha, it appeared probable that a considerable amount of the pyridine formed during the coking was not condensed either in the hydraulic main or in the tar separators and it seemed logical to expect that a considerable amount of this pyridine would be absorbed and retained by the acid saturator bath liquor in the ammonia saturators. Accordingly an investigation of the pyridine balance for the ammonia saturators in a by-product coke oven plant was undertaken. This work was done by Mr. Dodge and Mr. Rhodes at the plant of the Toledo Furnace Co., at Toledo, and by Mr. Dodge and Mr. Warner, at the Clairton By-Product Coke Plant of the Carnegie Steel Company. At each of these plants Koppers by-product coke ovens are used. The tar and some of the ammonia water are condensed in the usual way by passing the gases through hydraulic mains, primary coolers, and tar extractors. The tar-free gas is then reheated slightly and passed through the ammonia saturators, in which the gas is forced to bubble through a saturated solution of ammonium sulphate containing 6 to 10 per cent of free sulphuric acid. The ammonia-free gas is then passed to the benzol scrubbers and finally to the distributing mains. In the ammonia saturators ammonium sulphate is formed and precipitated from the solution and the solid ammonium sulphate is continuously removed and separated from the mother liquor by centrifuging, while the sulphuric acid concentra-

tion of the bath is continuously maintained at the desired point by addition of the fresh acid. The installations at the two plants were essentially similar, there being only slight differences in form of the individual pieces of apparatus and only minor differences in the operation.

The results of this work showed that a very considerable amount of the pyridine bases formed during the coking of the coal is not condensed with the tar but passes through the primary coolers and tar separators and is absorbed by the acid solution in the ammonia saturator baths. The work showed also that the pyridine sulphate thus formed remains in solution in the saturator bath liquor until the concentration of pyridine sulphate in the liquor reached a certain point, and that further absorption of pyridine by the bath liquor containing more than this critical amount of pyridine sulphate resulted in the separation of a portion of the pyridine sulphate with the ammonium sulphate crystals. For example, it was found that no pyridine could be detected in the salt from a bath containing 2.5 per cent pyridine and that the pyridine contained in a salt from a bath containing 7.5 per cent pyridine was almost one-quarter per cent. The work done at the coke ovens also showed that the amount of pyridine bases not condensed with the tar amounted to approximately from one-tenth to one-eighth of a pound per ton of coal coked.

On the basis of these results it was calculated that the total production of pyridine bases available from coke ovens which are operating in the United States and which use of the semi-direct sulphate process is approximately 446,000 gallons per year.

On the basis of the information which has been thus gained as to the amount of pyridine bases available in the saturator bath liquor an attempt was made to devise a practical process for separating and obtaining these bases in an essentially pure form. Because of the relatively small amount of bases present in the bath liquor at any one time, and because of the large loss of pyridine which occurred when the concentration of pyridine sulphate in the bath is allowed to rise above a certain very low point, it was evident that any process which would prove economically practicable must not involve the use of expensive chemicals and must not interfere with the normal operation of the plant.

Further investigation showed that if the pyridine containing mother liquor from the saturator bath is made alkaline by passing

ammonia through it, the pyridine bases originally present in combination as pyridine sulphate are liberated and separate from the saturated ammonium sulphate solution as a distinct layer. It was found, moreover, that if the neutralization of the acid solution was effected rapidly by bubbling through it a gas rich in ammonia, the heat generated by the reaction was sufficient to bring the solution to its boiling point and to steam-distill off the pyridine bases as fast as liberated. On the basis of this work a process for the recovery of pyridine from the ammonia saturator bath was developed and a plant suitable for operating this process was designed and installed in connection with the by-product coke oven

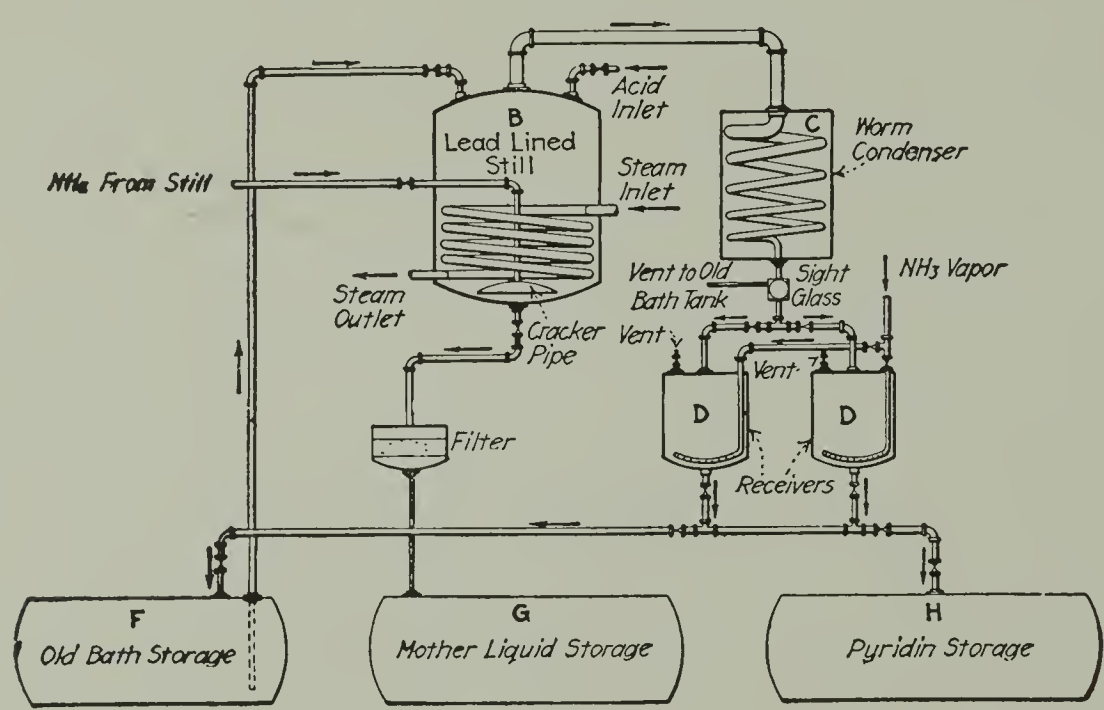


FIG. 1.

plant at Toledo. The design of this plant is shown diagrammatically in Fig. 1.

Tank "F" is a large storage tank for holding the saturator bath liquor before treatment to recover the pyridine bases. This is provided with an outlet to the hot drain tank, not shown, and with a discharge line leading to the pyridine still proper. "B" is a still in which the saturation of the bath liquor with ammonia vapor is effected. This still is leadlined and is shown provided with a steam coil for heating the liquor, which has not been found necessary, and with an inlet line for the admission of ammonia vapor. The ammonia vapor required for saturating the bath liquor is taken from the ammonia still, which ammonia still is operated to concentrate the weak liquor that separates from the gas with the

tar. The pyridine still itself is provided with a vapor pipe extending to the condenser and with a discharge line leading through a filter to the mother liquor storage tank. An acid inlet is also provided so that the final pyridine free liquor may be acidified before being discharged from the still. The mixture of pyridine vapor, ammonia, and water vapor coming from the pyridine still is condensed in the worm condenser "C" and the condensate is collected in receivers "DD," which are provided with discharge lines leading to the pyridine storage tank.

The operation of the plant is as follows: The ammonia saturators are run normally until the pyridine content increases to such a point that pyridine begins to appear in the solid ammonium sulphate as removed from the saturator. When this point is reached the saturator bath is discharged into the old bath storage tank "F" and a new bath is put in operation in the saturator. Sufficient of the material from tank "F" is then pumped to the pyridine still "B" to make a still charge. The solution is saturated with ammonia vapor until strongly alkaline. The heat of reaction raises the still charge to the boiling point and the mixture of pyridine vapor and water distills over, is condensed, and the condensate collects in the receivers. This condensate, as thus obtained, carries a considerable amount of water, and before this material is shipped or further worked up for pyridine it is desirable to remove as much as possible of this water. This is effected by agitating the material in the receivers with ammonium sulphate, adding approximately one pound of solid ammonium sulphate for each gallon of distillate. The ammonium sulphate absorbs and is dissolved in the water and the resulting saturated solution separates to the bottom of the receiver leaving an approximately dry pyridine as the upper layer. The ammonium sulphate solution is allowed to settle and drawn off to the old bath storage tank, while the dry pyridine bases are drawn off to the regular pyridine storage tank.

It has been found that when the old saturator bath is made neutral or alkaline by the passage of the ammonia vapors a blue or bluish black precipitate is formed. This precipitate consists apparently of finely divided free carbon or of a mixture of free carbon with ferro- and ferricyanides of iron. In order to remove this precipitate the liquor from the still is filtered through a small filter. The filtered liquor is then stored in the mother liquor storage tank "G." This filtered, pyridine-free liquor may be charged

directly to the ammonia saturators as a fresh saturator bath. We have found, however, that this filtered mother liquor may be used to very good advantage as a wash liquor for washing ammonium sulphate crystals in the centrifuges as they come from the saturator baths, since by using this liquor in this way it is possible to wash the crystals free from adhering impurities without incurring any danger of solution of the crystals.

It will be observed that this process involves a minimum amount of handling of various solutions. Moreover, no material is used which is not available in large amounts at any by-product coke oven plant, and the process as outlined does not interfere in any way with the normal operation. Finally, the only materials which are used in this process are ammonia and sulphuric acid and all of the ammonia and all of the sulphuric acid thus used are recovered as ammonium sulphate by the normal operation of the plant.

The plant erected at Toledo was on a semi-experimental scale only, and the production has not thus far been very large. However, several hundred gallons of pyridine bases have been produced at this plant and the results obtained appear to be very encouraging. The pyridine which has been produced has been essentially a crude light pyridine, distilling very largely below 200° C. The water content has varied considerably although several of the lots have shown only a trace of water. This pyridine as produced appears to be a very satisfactory crude pyridine for the preparation of refined pyridine bases for denaturing and chemical purposes. The extension of this process to other and larger coke oven installations should afford a supply of light pyridine bases adequate to the present or the immediately future needs of the country.

Since the development of this process a new and very interesting aspect of its application to the by-product coke oven industry has appeared. As is well known, the presence of pyridine is objectionable in sulphate of ammonia. The use of this pyridine recovery process in conjunction with the semi-direct ammonium sulphate process insures the absence of pyridine sulphate in the ammonium sulphate produced which is very desirable from several points of view.

ACID ELECTRIC-FURNACE FERROTUNGSTEN

By J. GLADING DAILEY

Read at the Savannah Meeting, Dec. 3, 1919

As has probably been inferred already, the term "acid," as used in the title of this paper, refers to the character of the slags formed as a result of the particular details outlined in this article as differentiated from the basic or high lime slags that normally result from the electric furnace manufacture of ferrotungsten.

Technical literature seems to indicate that previous to 1900 the making of ferrotungsten was carried out in crucibles; since 1900 the crucible practice has gradually fallen into disuse while electric furnace practice has correspondingly increased in favor.

Search of scientific literature, more particularly that available in English, affords little of real value on the subject of the actual quantity production of ferrotungsten or in fact of the ferro-alloys in general. Much of the information relates to small scale production or to experimental efforts. Some of the writers dilate at some length on the ease and facility with which satisfactory ferrotungsten can be made in the electric furnace; but closer scrutiny develops that they employ two-stage operations, the second being a so-called refining or decarbonizing smelt; their recoveries, as set forth, are poor and the resulting product, even after two smeltings, fails to meet the exacting specifications of the American high speed steel makers (foreign high-speed steel makers, more particularly the French are somewhat more liberal).

As an average the American high speed steel maker (crucible practice more particularly) demands ferrotungsten conforming to the following specifications:

Tungsten	not under	70.00%
Carbon	not over	0.60
Sulphur	" "	0.060
Phosphorus	" "	0.070

Silicon	"	"	0.60
Manganese	"	"	0.60
Oxygen	"	"	0.50
Lime	"	"	0.50

There are exceptions to this in that certain steel makers are somewhat more tolerant as to carbon; one large consumer permitting the carbon content to be as high as 1 per cent: a number of very important consumers, however, insist upon the carbon not being present in excess of 0.50 per cent and further a sulphur maximum of 0.050 per cent. Most of them insist upon freedom of the ferrotungsten from tin and copper. There are few tungsten ores that occur free of tin or copper; normal preliminary treatments fail to eliminate either tin or copper from tungsten ores and the electric furnace does so only to a degree. As a consequence steel makers have, unquestionably, taken, used and found entirely satisfactory supplies of ferrotungsten carrying appreciable quantities of either copper or tin and in cases, I have no doubt, both. Appreciable quantities, as here used, are intended to imply percentage between 0.025 and 0.100.

A comparison of the following analyses of typical ferrotungstens, made by the crucible and electric furnace processes may be interesting:

	Crucible	Electric Furnace	
		Silicious Slags.	Lime Slags.
Tungsten	61.86%	75.38%	75.50%
Carbon	1.17	0.53	0.52
Sulphur	0.042	0.040	0.040
Phosphorus	0.066	0.043	0.051
Silicon	0.48	0.48	0.46
Manganese	0.42	0.59	0.38
Lime	none	0.11	0.68

It must not be lost sight of that this crucible-produced ferrotungsten was probably made from more or less pure tungstic oxide and not by the direct reduction, in the crucible, of tungsten ores. The crucible-produced ferrotungsten averaged in the neighborhood of something over 60 per cent tungsten; at times perhaps reaching

65 per cent. Electric furnace ferrotungsten can be readily made to contain 75 per cent tungsten and, were specifications to demand it, a product exceeding 80 per cent tungsten could be regularly produced without working an undue hardship upon the ferro producers. The real difference between the two electric furnace ferros above is in their lime content. Lime in ferrotungsten is undesirable from the standpoint of the crucible high speed steel maker. It detracts from the life of his pots. He tries to guard against it by specifying low lime and he tries to correct for it by adding sand to his crucible charge. I have seen basic slag ferrotungstens come on the market with a lime content in the neighborhood of 3 per cent.

To the extent of my knowledge there has been but one maker of acid electric furnace ferrotungsten in the United States. Mr. R. M. Keeney, in his article on "The Manufacture of Ferroalloys in the Electric Furnace," Bulletin No. 140 of the American Institute of Mining Engineers, August, 1918, page 1341, says: "Ferrotungsten containing less than 1 per cent carbon can be made in a single operation, by careful regulation of the carbon in the charge, and the use of an acid slag. The disadvantage of this method is that the product is less pure and the slag loss is considerably higher; the metal will contain much higher phosphorus and sulphur, and the total loss of tungsten may be 25 per cent as compared with 10 to 15 per cent by the two-stage process."

The writer's experience, in the making of over 750,000 pounds of contained tungsten in marketable ferrotungsten, fails to confirm the disadvantages attributed to the use of acid slags. Such slags are fluid and of relatively low specific gravity and viscosity; as a consequence of their chemical make-up tungsten, being acid itself in general character, is less liable to enter, chemically, into such acid slags and cause slag losses.

The operations productive of the above quantity of contained tungsten in acid electric furnace ferrotungsten were of the one-stage type; the ores were such as the market afforded (largely South American wolframite-huebnerite mixtures and Asiatic huebnerites); they received no preliminary treatment aside from coarse grinding and roasting, and the tungsten losses were appreciably under 10 per cent with corresponding tungsten recoveries in excess of 90 per cent.

In arriving at these figures the plant was charged with the

tungsten paid for on the basis of independent weighing, sampling and analysis of all ores coming into the plant and the recovery figures took into account the actual tungsten paid for in the form of ferrotungsten shipped from the plant.

For the past two or three years practically three-fourths of the world's supply of tungsten ores was mined in four countries; Burma and the Shan States, the United States, Bolivia and Portugal. Comparatively little of the Asiatic and none of the Portuguese ores came on the American market during 1917. During 1918 quite a tonnage of Asiatic ores actually came on the American market and considerably larger amounts were freely offered for contract and future delivery. The Bolivian ores, more particularly those from the District of Oruro, are wolframites unusually low in manganese, many consignments containing under 1 per cent and in this respect containing less manganese than the famous low mangaese Colorado ferberites. Everything else being equal, the low manganese wolframites are to be preferred as they contain ample iron to provide for the iron requirements of the ferrotungsten and the slag. Huebnerites—and most of the Peruvian and Asiatic ores are huebnerites—are somewhat less desirable, as they cut down furnace capacities because the charge must carry hammer-scale or iron ores to make up for their (the huebnerites') deficiencies in iron. Sufficient scheelite never became available to make protracted quantity runs using this important naturally occurring lime salt of tungstic acid.

Furnace Conditions

The furnaces were the simplest imaginable, being but brick boxes, open at the top. They measured inside about 32 in. long by 20 in. wide by 28 or 30 in. deep. They were built on cast-iron base-plates elevated above the floor a sufficient height to permit a truck being run under the base-plate and thus remove a furnace at the end of its run and replace it with a new furnace. The furnaces first used were of fire brick but as these advanced in price and became correspondingly more difficult to obtain subsequent furnaces were constructed of ordinarily locally produced red building brick of the commoner sort. These cheaper red brick furnaces were equally as satisfactory as those of fire brick construction. A furnace of the dimensions given is intended as a two-phase furnace with two 6 in. round amorphous carbon screw-joint elec-

trodes; these are centrally located with about 16 in. between centers. Larger three-phase furnaces with three electrodes were used from time to time with an increase in production and a lowering of the current consumption per pound of contained tungsten in marketable ferrotungsten; but the larger "buttons" of ferrotungsten resulting from these three electrode furnaces imposed difficulties in breaking them up.

Current was supplied through two 500 K.V.A. and two 200 K.V.A. Pittsburgh transformers; high side 13,200 volts and tapped from these transformers at 50 volts; 25 cycles. Voltage at the electrode holders directly over the furnaces averaged from 43 to 46 volts. Current 900 to 1000 amperes. Runs were usually of 30 hours duration and the buttons yielded, on an average, about 1800 pounds of 75 per cent ferrotungsten.

Under the conditions just referred to low manganese wolframite ores can be reduced and a marketable grade of ferrotungsten produced (carbon in the neighborhood of 0.50 per cent or under this figure if desired and low in phosphorus and sulphur) at a current consumption of about 1.6 K.W.H. per pound of contained tungsten; correspondingly, high manganese ores (huebnerites) can be likewise successfully treated with a current consumption of about 1.75 K.W.H. per pound of contained tungsten.

It has been assumed as common knowledge that a marketable grade of ferrotungsten cannot be successfully tapped from the furnace. The slag only is tapped off and the ferrotungsten, from successive additions of ore, allowed to accumulate until the furnace is almost full when, as already stated, the furnace is removed from its position on a truck and allowed to cool. This requires at least 24 hours. Were the mass broken into while still red hot the ferrotungsten would at least discolor because of oxidation wherever exposed to the air and if sufficiently hot would oxidize superficially to WO_3, which would coat all exposed surfaces with this characteristic yellowish-green powder and thus contaminate the finished product with oxide.

Three products result from the taking-down of a furnace and the breaking-up of a button therefrom.

1. Marketable ferrotungsten which is broken up by means of drop-balls, sledges, air-hammers or such other means as may find favor with the individual operator; followed by crushing, sampling and kegging.

2. An intermediate which must be re-handled in the furnaces. The treatment of this particular product will be given in detail later under the designation Reclamation Material "B."

3. A mixture of unreduced ore and charge from the furnace corners together with "cap" and brick trimmings, too high in tungsten content to discard. This is called either Reclamation Material "C" or more frequently Furnace Trimmings.

Charge Calculations

Charges going into the furnaces are of two general sorts and will be treated separately. The are ore charges and reclamation material B charges.

Ore charges, of themselves, fall into two classes as regards their calculation: 1. Those carrying sufficient iron to provide for the ferrotungsten to result therefrom together with the demands of the slags. Low manganese wolframites from Bolivia and ferberites from Colorado fall into this class. 2. Those carrying an insufficiency of iron to meet these requirements. Peruvian and Asiatic huebnerites and all scheelites fall into this class. Scheelite was not extensively used consequently no data of value are available relative to its use; but it seems reasonable that the conditions applied to huebnerites are equally applicable to scheelites.

In figuring an ore charge it is essential to first see that sufficient iron be present to make a ferrotungsten of the grade sought, say one containing 75 per cent tungsten and 25 per cent iron. It is not necessary to take into consideration, at this time, small percentages of impurities subsequently found in the resulting ferrotungsten such as carbon, silicon, manganese, etc. Iron must also be provided for the slag on the basis of the slags tapped containing 8 per cent iron. Obviously, at this point, when considering the slag make-up, considerable elasticity is permissible.

Any deficiency in iron may be corrected for by adding high speed scale, hammer or roller mill scale, iron ores or similar iron-bearing materials. It is advisable that such products be of low sulphur and phosphorus content.

Carbon is then calculated into the charge in sufficient amount to provide for: 1. The reduction of all the WO_3 in the ore and high speed scale to W. 2. The reduction of sufficient iron from the ore and added iron bearing materials to make a 75 per cent

ferrotungsten. 3. The reduction of the remaining iron, from such state of oxidation as it may be in, to FeO. This is the iron going into the slag. All carbon should be calculated to form CO.

Experience has taught that 95 per cent of the quantity of carbon as above theoretically required must be added to the charge in the form of fixed carbon, preferably in low sulphur and phosphorus petroleum coke, although ordinary coke, coke breeze, anthracite coal, etc., can be successfully used. The deficiency of carbon indicated by the use of but 95 per cent of the amount theroetically required is made up by carbon contributed by the electrodes. Iron in the scale can be considered as in the form of Fe_3O_4.

All materials going into the charge or mix should be in the same state of fineness or subdivision. A 10 mesh to 4 mesh product, for an unbriquetted charge, having been found best suited. Finely ground charges, if not briquetted, suffer excessive losses because the furnace gases carry appreciable quantities away. Coarse charges (in excess of one-quarter inch particles) fail to properly reduce for a variety of reasons, and in addition coarse carbon or coke particles, if any appreciable amount of the reducing carbon is in this coarse condition in the charge, become graphitized and as such loses materially its reducing ability.

It appears to be a demonstrated fact that carbon, in the presence of Fe_3O_4, WO_3, and FeO, exerts preferential reducing action; first reducing the Fe_3O_4 to FeO; then the WO_3 to W and finally the FeO to Fe. Furnace charges carrying an insufficiency of carbon produce when smelted, honeycombed masses of ferrotungsten analyzing 90 per cent or higher in tungsten, the slags being found correspondingly high in iron. Such high-iron slags are very characteristic and easily recognized. They usually run relatively high in tungsten also containing 3 to 6 per cent or more if the carbon deficiency is aggravated, as compared with one-half of 1 per cent or less tungsten; the normal acid slag.

The following are representative furnace mixes using both sorts of ore already referred to.

TYPICAL ORE ANALYSES

	Low Manganese Bolivian Wolframite.	High Manganese Asiatic Huebnerite.
Tungstic oxide	69.75%	71.12%
Ferrous oxide, FeO	23.29	10.38
Manganous oxide	0.83	13.82
Lime, CaO	1.06	0.53
Silica	3.45	2.15
Sulphur	0.125	0.200
Phosphorus	0.031	0.018
Copper	0.05	0.06
Tin	0.16	0.43
W : Fe ratio	75.48	87.50

The above ores had been roasted to eliminate sulphur and frequently arsenic. Analyses represent roasted ores.

FURNACE CHARGES FOR THESE ORES

	Low Manganese.	High Manganese.
Ore	300 lbs.	300 lbs.
Coke, 90 per cent fixed carbon	40 "	53 "
HS scale, 60 per cent iron	...	51 "
Furnace trimmings	40 "	...
Sand, 95 per cent SiO_2	...	30 "
Lime, 63 per cent CaO	5 "	10 "
Fluorspar	5 "	5 "
Common salt, NaCl	3 "	3 "

TYPICAL SLAGS FROM THESE CHARGES

	Low Manganese.	High Manganese.
Tungstic oxide	0.44%	0.78%
Ferrous oxide	11.21	10.50
Manganous oxide	3.02	17.20
Lime	18.72	13.25
Silica	44.54	53.78
Alumina	20.79	3.25
Sulphur	0.38	0.26

The high alumina content is derived from the furnace trimmings going into these low manganese charges. These have already

been referred to as Reclamation Material "C." A varying amount of this intermediate is gotten when the furnaces are torn down. It is largely the furnace brick that has come into contact with the tungsten-bearing charge and carries, consequently, too much tungsten to warrant its being discarded. It is disposed of and kept from accumulating by mixing it with the ore charge. Such an intermediate varies greatly in tungsten content. It may assay from 3 to 8 per cent tungsten.

Ferrotungsten resulting from one-stage smelting operations of the foregoing ores, mixed as indicated would be fairly well represented by the following analysis, which is simply one of many such lots:

Tungsten	75.73%
Carbon	0.47
Sulphur	0.037
Phosphorus	0.038
Silicon	0.48
Manganese	0.56
Lime	0.10

Reclamation Material "B"

Varying amounts of this product result from the breaking up of each button. Ideal heat conditions, during the run, minimize the amount of this product with a corresponding increase in the quantity of marketable ferrotungsten; but, as the furnaces are hand-operated with respect to the raising and lowering of the carbon electrodes and thus the maintainance of arc conditions and in addition are operated over the 24 hours of the day (three eight hour shifts), the changing of crews and work of different metermen introduces widely varying human factors which is reflected in the make-up of the resulting buttons.

This Reclamation Material "B" is not marketable as such; so must be treated to get its high tungsten content into marketable ferrotungsten. These intermediates are surprisingly uniform in composition. In color they are varying shades of gray. They are tough, heavy and compact but relatively easily crushed as compared with ferrotungsten. In the button it is found as an enveloping layer completely surrounding the button-core of ferrotungsten on

all sides. Its tungsten and iron content have suffered complete reduction; but heat conditions have not been sufficiently high to bring about fusion or plasticity which would have united its iron and tungsten content with the ferro already formed and separated its slag-forming constituents.

A typical Reclamation Material "B" intermediate analyzes as follows:

Tungsten	48.85%
Iron	19.31
Carbon	1.53
Sulphur	0.115
W: Fe ratio equals ferro of	71.67

To make ferrotungsten containing 75 per cent tungsten and of acceptable carbon content (0.50 to 0.60 per cent C) from this intermediate the tungsten-iron ratio must be raised and the carbon content lowered. Obviously this can be accomplished in several ways. The use of tungstic oxides and tungsten ore for this purpose readily suggest themselves. Both these expedients work out satisfactorily.

In the practice under discussion we have normally pursued a somewhat different course. It has been found that this type of intermediate, when finely ground (10 mesh or finer in Lehigh Fuller mills or Sturtevant ring rolls) suffers oxidation if moistened and exposed to the air. This oxidation is hastened by stirring the finely ground, moistened material in any heavy duty mixer such as one of the Werner-Pfliederer type. Ten minutes of such stirring or mixing, keeping the material just damp, suffices to bring about oxidation that heats up the product to a temperature at which the hand cannot be kept in contact with it. Clouds of vapor arise. They have an odor of hydrocarbons but repeated tests before and after such "rusting" process have failed to evidence any corresponding or rather commensurate loss in carbon content. The carbon remaining in the "rusted" material is sufficient to again reduce such tungsten as may have been oxidized by "rusting" but the greater part of the iron oxidized at the same time passed into the slag upon smelting. In this manner the tungsten-iron ratio is increased to the point desired and the carbon correspondingly lowered.

A typical mix for furnace charges of a "rusted" product such as has just been described would be the following:

Reclamation Material "B"	400 lbs.
Furnace Trimmings	40 "
Common Salt, NaCl	4 "

Such mixes may be used in combination with ore charges or they may constitute the sole charge going into the furnaces. In the latter case, obviously, the duration of the furnace run would be considerably under the 30 hours allotted for ore runs, as such a charge would be materially richer in tungsten, would require melting only, would make ferrotungsten much faster, thus filling the furnaces in a much shorter time.

Furnace Operations

The two-electrode furnaces of the style described earlier in this paper have a thin slab of carbon imbedded in the center of the fire-brick floor (even those furnaces built of ordinary common red building brick had their floors constructed of fire-brick; building brick size 2x4x8 in.). This carbon slab was just long enough to reach from one electrode to the other and deep enough to preserve electrical contact between the inside of the furnace and the cast-iron base-plate upon which the furnaces were built. This slab is useful in starting the furnace but is by no means essential for this purpose. Its sole function is to insure contact with the controlling instruments.

These cast-iron base-plates were then connected with the instruments for controlling the energy input into the furnaces. Two ammeters and one voltmeter were used for each such furnace. The arc conditions, as reflected on these instruments, being maintained or corrected by handwheels attached to winches whereby the cables connecting with the electrodes could be lengthened or shortened and the electrodes lowered or raised.

In starting a furnace from 300 to 500 pounds of dry charge was gradually introduced and brought to a condition of active fusion. The furnace was then filled, as rapidly as possible, with wet charge; charge which had been made to the consistency of a stiff mud or paste with water. Charge of this character was delivered to the furnace room by the mixing crews.

The furnace was filled to the top with such wet charge and the top of the charge, gradually sloping, was mounded or peaked

to the points where the electrodes passed down through. This mounded top is called the "cap" and is kept wet by sprinkling with water at frequent intervals. It is kept smooth and in condition by being smoothed over with trowels after such sprinkling.

Four holes or vents are made through the finished "cap" by driving iron bars or wooden sticks (about 1 in. in thickness) through the "cap" to the fusion zone below. Usually one such vent in each of the four corners of the furnace suffices. These vents incline from the corners toward the arcs. Immediately after filling the furnace the gases from these vents is largely steam; but after 15 or 20 minutes the gases ignite and burn. From then on until tapping time they are largely CO colored by sodium from the salt.

Normally the slag is tapped at four hour intervals. Toward the end of the four hour slag tapping intervals the "cap" becomes quite thin. It averages roughly about 6 in. in thickness at the time of tapping. The "cap" usually remains intact until the slag has been tapped, at the end of which operation the slag hole is blocked up and the "cap" broken in and the furnace immediately filled, as above described, with wet charge.

The small quantity of salt is added to the charge to assist in keeping the "cap" intact until after the tapping off of the slag. Other materials have been successfully substituted for this purpose, among them soda ash, borax, sodium silicate and others and while they act equally well as salt in keeping the "cap" intact yet disadvantages attend their use.

At the end of the 30-hour furnace run the stack is full to within 8 or 10 in. of the top. Toward the end of the run it becomes increasingly difficult to keep the "cap" intact. Upon closing down a furnace it is immediately replaced by a new one. This replacement, under favorable conditions can be done in from 30 to 40 min. It averages about one hour, as there are frequently minor repairs needing attention. After closing down a furnace it must be allowed to cool for at least 24 hours, at the end of which cooling period the bricks are stripped off and the pillar of ferrotungsten enveloped in its layer of reclamation materials is called the "button." Depending upon the character of the charge it may weigh from 2000 to 5000 lbs.

Handling the Buttons

The breaking up of these large "buttons" and in fact the smaller ones as well weighing 500 to 1500 lbs. resulting from the small pot single electrode operations, imposes quite a problem on the ferrotungsten makers. Drop-balls, hand sledging, and air hammers have been used with a varying degree of success.

The buttons are far from uniform. The centers are compact, finely crystalline, relatively brittle in character. This material assays well over 80 per cent tungsten and well under 0.50 per cent carbon. Masses of these cores could be readily selected that would assay 88 to 90 per cent tungsten and under 0.20 per cent carbon. The further from the center the higher the carbon content becomes and the lower the tungsten. The lowest grade of actual ferrotungsten usually encountered contains 70 to 72 per cent tungsten and 0.80 to 1.20 per cent carbon. All the ferrotungsten is lotted together and so lotted will run 73 to 76 per cent tungsten and 0.50 to 0.60 carbon.

From the relatively low grade ferrotungsten the button gradually, in the space of 2 or 3 in., passes into the Reclamation Material "B" which acts as the button envelope.

Ferrotungsten lends itself readily to easy separation of the various grades such as have just been referred to. They are very different in appearance and hand sorting can be easily and accurately done. They are very different in their behavior toward strong magnetic fields; separation, by this means, being very sharp and correspondingly satisfactory.

Separation by electro-static means offers possibilities; personally only experimental tests have been made in this field.

Résumé

In general the advantages of making acid electric furnace ferrotungsten are the higher recoveries because of the lessened tendency of tungsten to go into a slag of high silica content as compared to its tendency to readily enter basic slags high in lime and the production of a ferrotungsten practically free of lime. The principal and only practical disadvantage is that ores must be more nearly "dead roasted" to free them of sulphur and arsenic than should be necessary under more basic conditions where the lime can be

depended upon to slag off greater amounts of these elements than would thus be removed by silicious slags.

Incidentally very efficient roasting practice was developed as a result of which tungsten ores with sulphur in excess of 4.0 per cent and arsenic correspondingly high could be roasted to a sulphur content of 0.10 per cent or less with a tungsten loss of appreciably less than 1.0 per cent. Gas was used in a rotary inclined roaster. It was automatically hopper-fed with a 10 mesh product or at times a 4 mesh product depending upon the character of the ore. This roaster had a capacity of from 300 to 500 lbs. of practically dead roasted ore hourly.

Summary

1. Ferrotungsten assaying 75 per cent tungsten and about 0.50 per cent carbon can be readily produced by one-stage smelting under conditions productive of acid slags.

2. Tungsten recoveries in excess of 90 per cent are obtainable.

3. Current consumption of about 1.6 K.W.H. per lb. of tungsten produced from low manganese wolframites and 1.75 K.W.H. per pound of tungsten produced from high manganese huebnerites.

4. Ores must be well roasted in order to insure a ferrotungsten of low sulphur content.

5. Resulting ferrotungsten practically lime free.

6. Details of charge calculations, furnace operations, current conditions and handling of intermediates are given.

REPORT OF THE COMMITEE ON CHEMICAL ENGINEERING EDUCATION

By JAMES R. WITHROW

Read at the Savannah Meeting, Dec. 3, 1919

It has been suggested by our host that reports at this meeting should be brief in order to the better enjoy Savannah's hospitality.

At the Boston Meeting your Committee requested information as to those in attendance who had not received a copy of the Mann Report on Engineering Education. The late arrival of the boat from New York frustrated your committee's request for the securing of such data at registration. For some reason or other your committee's request for a polling of the meeting was not complied with. We were therefore left with the alternative of mailing a request to the membership authorized at the Boston Meeting. However, to save time and expense, your chairman made a personal visit to the Carnegie Foundation Offices in New York and arranged with Dr. Clyde Furst and Dr. I. L. Kandel of the Carnegie Foundation for the Advancement of Teaching to send a copy of the Report by Dr. Mann to the full membership list of the Institute, whether they had previously received copies or not. Dr. Furst later informed us that our Secretary, Dr. Olsen, was assisting by the addressing of labels in his office. The distribution of these copies of the Report by the Foundation had reached the end of the alphabet by the middle of November. They have been detained probably by affairs in New York. We, however, are grateful to the Carnegie Foundation for this gift involving some little expense and thank the Foundation for its hearty co-operation.

These copies should now be in the hands of every member.

It is the intention of the committee, now that the members have the Mann Report, to get out, after this meeting, a questionnaire calculated to bring out to the members the salient features of the Mann Report and also to draw out the present-day point of view of the membership on the subject of chemical engineering education as

authorized at the Boston Meeting. The advantages of this will be obvious since we have not taken such a census for over five years.

Your Chairman had hoped to assist in this direction by preparing a discussion of Dr. Mann's Report early enough to be printed before this meeting, had not influenza prevented.

Attention is called to the fact that the Society for the Promotion of Engineering Education has actively taken up some of Dr. Mann's suggestions and is co-operating with engineering colleges throughout the country in the application of "nut-tests" to freshmen in an effort to locate the cause of high mortality among such students in the engineering courses.

We ask that the acceptance of this report carry with it the vote of the Institute to officially thank the Carnegie Foundation for the Advancement of Teaching, through our Secretary, for its gift of copies of the Mann Report on Engineering Education to the individual membership of the Institute and for the Foundation's hearty co-operation in the efforts of your committee to interest our membership in this fundamentally important work in Engineering Education carried out by the Foundation.

We ask also that the acceptance of this report carry with it instructions to the Secretary to send out a notice to the membership immediately after this meeting calling the attention of the membership to the sending to them of the Mann Report, asking that those who did not receive a copy notify the Secretary or your chairman at once.

(Signed) JAMES R. WITHROW,
Chairman.

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